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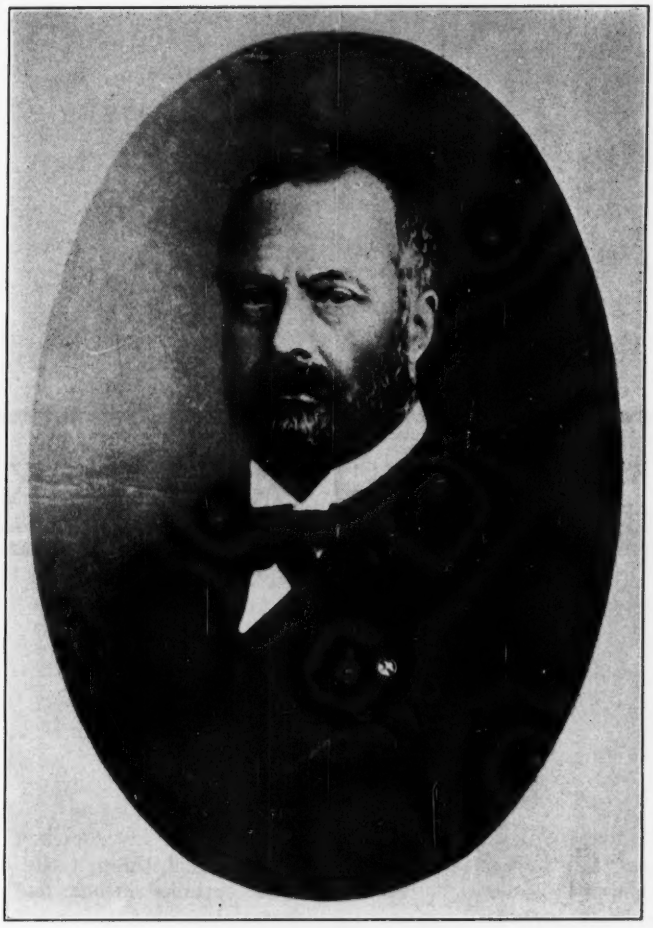

HENRI SAINTE-CLAIRE DEVILLE (1818–1881)

Henri Sainte-Claire Deville was born on March 11, 1818 on the island of Saint Thomas in the Antilles where his father was French consul. Both he and his older brother Charles, the geologist, were educated at Paris. He first studied medicine and took courses in chemistry at the Sorbonne under Thénard. His predelection for chemistry was soon demonstrated, and as early as 1839 he published his first paper on turpentine. This was followed, two years later, by another article, on Tolu balsam in which he had discovered the presence of toluene. Through the influence of Thénard, Deville at the age of twenty-six, was made dean of the newly organized faculty of Besancon. In addition to his official duties, Deville undertook the examination of the potable waters of the region around Besancon and recognized, for the first time, the presence of nitrates in the water supply. In 1851 he was recalled to Paris where he became professor at the Sorbonne and director of the laboratory of the École Normale Supérieure. Here he conducted his celebrated researches on the large-scale production of sodium and aluminium (1854). It is stated by A. Letellier that the first ingot of aluminium was actually cast at the palace "La Damette" at Irigny where a number of noted chemists used to meet and perform experiments at the invitation of the owner, a silk manufacturer of Lyon. Deville's work on gaseous dissociation started about 1857 with a publication entitled "The Dissociation and Spontaneous Decomposition of Substances by Heat." His experiments on the dissociation of carbon dioxide were performed by means of a cold-warm tube in which the dissociated gases were removed through a small orifice in a silver tube in which a stream of cold water was maintained. This work was carried out first alone and later in cooperation with his pupil and "faithful interpreter" (according to Duhem) Henri Debray.

His most famous student and, after Moissan's death, his distant successor, was Le Chatelier who has left us a vivid picture of his teacher in the preface to his book, "Lecons sur le Carbone," published in 1908. Small of stature, vivacious in his speech, with rapid movements, Deville delighted his hearers at the Sorbonne with his anecdotic stories of the dog and the bone, the black phosphorus, and similar amusing tales. The absence of factual knowledge in Deville's lectures was at first keenly felt as a distinct disadvantage and yet, by stimulating the imagination of the audience, so Le Chatelier says, Deville made his students think for themselves, which—after all—is the main purpose of all oral instruction. Coming from one so renowned who owed his intellectual formation to Deville, this statement leaves us with the impression that Deville was not only a great scientist but also a most successful teacher.

(*Contributed by H. S. Van Klooster, Rensselaer Polytechnic Institute*)

EDITOR'S OUTLOOK

WITH THIS ISSUE, the JOURNAL OF CHEMICAL EDUCATION begins its seventeenth year. From small and unpretentious beginnings, the JOURNAL has become a vital factor in chemical education in America. Its high standard of quality has been due in large part to the efforts of two men who have been outstanding in their interest in chemical education, Dr. Neil E. Gordon and Dr. Otto Reinmuth, the JOURNAL'S only editors.

The Board of Publication regrets to announce that on August 1, 1940, Dr. Reinmuth will retire as Editor of the JOURNAL OF CHEMICAL EDUCATION. Dr. Reinmuth has been untiring in his effort to maintain a journal of superior quality. Quiet and unassuming, he has given to the JOURNAL a scholarly atmosphere that will challenge any successor. To maintain a worthwhile journal through the lean years of 1930–1940 under curtailed income and budget has required resourcefulness and patience.

The Board of Publication and the Division of Chemical Education wish to take this means of expressing to Dr. Reinmuth their sincere thanks and appreciation for his excellent work and unfailing coöperation.

BOARD OF PUBLICATION, JOURNAL OF CHEMICAL EDUCATION

and

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The ATOMIC HYPOTHESIS *of* WILLIAM HIGGINS[1]

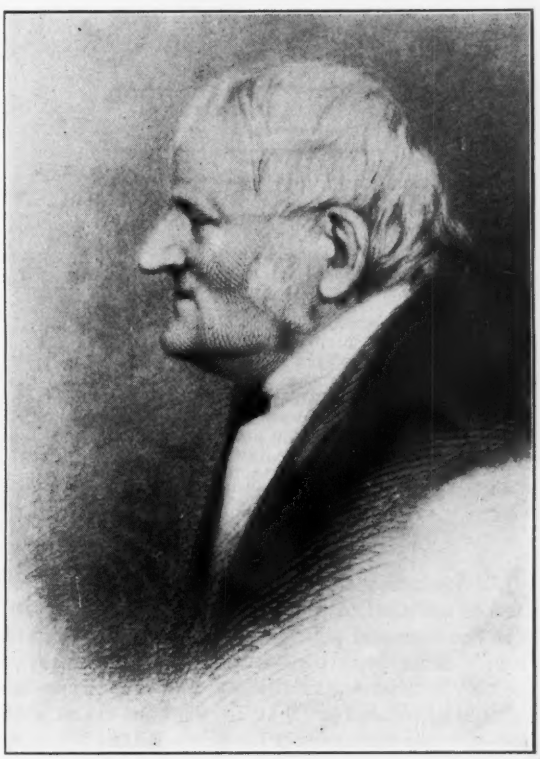
EDWARD R. ATKINSON

University of New Hampshire, Durham, New Hampshire

IN CONCLUDING his formal claim to having been the first to apply the concept of atoms to chemical science, some fifteen years before John Dalton, William Higgins said, "The generous age of chemical science is no more. In my early days, it was my fortune to live at the same time, and to associate with, many of the venerable fathers of our present system. In that auspicious period, the ultimate and ardently expected object of research was truth: not the advancement of an individual's reputation. Philosophers were then eager to attribute the merit of discovery to its rightful owner, not to appropriate it to themselves or others. But now, in the vale of life, I am myself obliged to rescue the labours of my youth from the claims of those, who have adopted them without ceremony, and who have even attempted to force them from me by means of their combined exertions. However, justice will force its way sooner or later against all obstacles and prejudices. The subject is not, now, confined to the decision of a few individuals, but is laid before a grand tribunal, and it rests with them to give a verdict."[2]

The verdict rendered by the chemists of the last century is not a just one because they have been content to accept the Dalton myth which, as will be shown later, originated with a particularly biased contemporary of Higgins and Dalton. It is the purpose of the present study to show, by citation of original source material, that William Higgins was indeed the first to introduce the atomic hypothesis to chemistry, and that this introduction did not consist merely of "brilliant conceptions, hastily struck off (rather) than the fruits of sober and sustained induction," as Henry has claimed.[3]

During this study the author has been fortunate to have for his use copies both of the rare first edition of Higgins' "A Comparative View of the Phlogistic and Antiphlogistic Theories, with Inductions"[4] in which the atomic hypothesis is introduced, and of Higgins' "Experiments and Observations on the Atomic Theory and Electrical Phenomena."[2,5] The author is indebted to previous writers on this subject[6,7] for stimulating ideas; and to Professor Tenney L. Davis of the Massachusetts Institute of Technology for his help in obtaining certain source material.



Courtesy of Dr. Harold Hibbert of McGill University

JOHN DALTON

WILLIAM HIGGINS

William Higgins was born in 1766, in County Sligo, Ireland. He was a nephew of the phlogistian, Dr.

[1] Presented before the Division of the History of Chemistry at the ninety-eighth meeting of the A. C. S., Boston, Mass., September 12, 1939.

[2] HIGGINS, "Experiments and observations on the atomic theory and electrical phenomena," Longman, Hurst, Rees, Orme, and Brown, London, **1814,** 180 pp.

[3] HENRY, "Memoirs of the life and scientific researches of John Dalton," The Cavendish Society, London, **1854.**

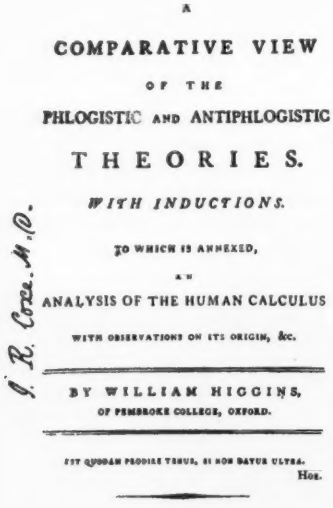
[4] HIGGINS, "A comparative view of the phlogistic and antiphlogistic theories, with inductions," 1st ed., J. Murray, London, **1789,** xiv + 316 pp. A second edition appeared in 1791.

[5] These books were kindly loaned by the Chemistry Department, Trinity College, Hartford, Conn.

[6] REILLY AND MACSWEENEY, *Sci. Proc. Roy. Dublin Soc.*, **19,** 139 (1929).

[7] WHITE, *Science Progress*, **24,** 300 (1929).

Bryan Higgins, from whom he received his early instruction in chemistry; hence in his noted attack on phlogiston in the "Comparative View" he says, "I have written with conviction and without prejudice (otherwise it would be natural to suppose, that I would join my countrymen in defence of that doctrine in which I have had my early instructions in chemis-



A

COMPARATIVE VIEW

OF THE

PHLOGISTIC AND ANTIPHLOGISTIC

THEORIES.

WITH INDUCTIONS.

TO WHICH IS ANNEXED,

AN

ANALYSIS OF THE HUMAN CALCULUS

WITH OBSERVATIONS ON ITS ORIGIN, &c.

BY WILLIAM HIGGINS,

OF PEMBROKE COLLEGE, OXFORD.

FIT QUODAM PRODIRE TENUS, SI NON DATUR ULTRA.

HOR.

LONDON:

PRINTED FOR J. MURRAY, NO. 32, FLEET-STREET.

M,DCC,LXXXIX.

J. R. Coxe. M.D.

FIGURE 1.—TITLE PAGE OF THE FIRST EDITION OF HIGGINS' "COMPARATIVE VIEW." THIS COPY BEARS THE SIGNATURE OF JOHN REDMAN COXE (1773–1864) WHO WAS PROFESSOR OF CHEMISTRY AT THE UNIVERSITY OF PENNSYLVANIA FROM 1809 TO 1819. AT THE TIME OF HIS DEATH HIS LIBRARY, "THE BEST COLLECTION OF THE FATHERS OF MEDICINE AND OF THEOLOGY" WAS SOLD AT AUCTION

try)." He attended Pembroke College, Oxford, and acted as assistant to the popular Dr. Beddoes. While there he wrote and published (1789) his "Comparative View." Since later considerations of this work will deal only with its contributions to the atomic hypothesis it should be pointed out that this vigorous experimental support of the principles of Lavoisier did much to cause Kirwan and other noted phlogistians to recant.

In 1791 Higgins was appointed superintendent of Apothecaries Hall, Dublin. He became a member of the Royal Dublin Society in 1794 and professor of chemistry and mineralogy to the Society in 1800. He held this latter post until his death in 1825. His only other formal publication was a book on bleaching which appeared in 1799.[8] Additional biographical material is given by Reilly and MacSweeney.[6]

[8] HIGGINS, "Essay on the theory and practice of bleaching wherein sulphuret of lime is recommended as a substitute for potash," London, 1799.

THE CONTRIBUTIONS OF WILLIAM HIGGINS TO THE ATOMIC HYPOTHESIS

That matter is composed in its ultimate division of discrete particles was first postulated by the Greek philosophers, Leucippus, Democritus, and Epicurus, and this same concept was later restated by Sir Isaac Newton in the "Principia"; it also appears in the writings of Locke and Boerhaave. There is no undisputed evidence, however, that this idea was applied to explain the facts of chemistry before the time of Higgins and Dalton. It is commonly supposed that Dalton conceived of elementary particles of characteristic weights to explain the facts stated in the Law of Multiple Proportions. According to Roscoe and Harden[9] examination of Dalton's notebooks, found in the rooms of the Literary and Philosophical Society

Courtesy of Graham Lusk

ANTONINE-LAURENT LAVOISIER

of Manchester, indicates that he approached the hypothesis from a physical standpoint, as had Newton, and subsequently used the hypothesis to discover the facts of multiple proportions. Higgins, on the other hand, was thoroughly conversant with many such facts, discovered by him and by Lavoisier during the work on phlogiston. The application of the atomic hypothesis by Higgins followed an understanding of the Law of Multiple Proportions. Regardless of approach, the enunciation of the atomic hypothesis was essentially the same as that given later by Dalton, and Higgins on the whole seems satisfied with Dalton's presentation.[2] We wish to show, however, that Higgins used such a hypothesis about fifteen years prior to Dalton, whose first recorded use of the hypothesis was in 1802.[10]

[9] ROSCOE AND HARDEN, "A new view of Dalton's atomic theory," The Macmillan Co., New York City, 1896.

[10] DALTON, "Experimental enquiry into the proportion of the several gases or elastic fluids, constituting the atmosphere." Read November 12, 1802. From the "Memoirs of the Literary

For this purpose excerpts from the first edition of Higgins' "Comparative View" have been selected.[11] Some of these were cited by Higgins twenty-five years later in his "Atomic Theory" upon the occasion of his formal claim as originator of the atomic hypothesis. His quotations at that time are not exact ones for as he says, "When I had written the present chemical nomenclature was not adopted: ..... Modernising, therefore, that part of my book which must necessarily be transcribed, cannot be considered misrepresentation. In many instances, it will be necessary to render passages shorter and more perspicuous than they are in the original, particularly as this doctrine was applied to abstruse investigation, as I have already mentioned. There shall be no alteration whatever, as to the mere matter of fact....." Although no use of the "modernised" quotations will be made, it will be instructive to include a few comments made by Higgins in 1814 when he published these quotations in his "Atomic Theory."

Since the "Comparative View" was concerned chiefly with the problem of phlogiston, references to the use of an atomic hypothesis must be sought in the description of experimental work and discussion thereof rather than in any formal statement. On page viii of the Introduction, Higgins says, "Thus seeing upon what principles the phlogistians and antiphlogistians maintained their different doctrines, and the impossibility of persuading us by experiments alone, from what only exists in our imagination, so prone are we to reconcile every phenomenon we see to our manner of thinking, I was obliged to have recourse to a mode of reasoning rather novel in chemistry." This novel mode of reasoning, he later says, was the atomic hypothesis.

It is admitted that the use of the term "ultimate particle," later used also by Dalton,[12] goes no farther than the Greek philosophers and Newton. For this reason it would not be proper to state that excerpts similar to the following aid Higgins' case,[13] "Though its aggregate attraction appears weaker than that of iron, from its facility of pulverization; yet when reduced into powder, or small molecules, its ultimate particles may cohere with greater force." There is considerable evidence, however, to show that by *ultimate particle* Higgins had the same idea which Dalton expressed by the term *atom*. In the "Atomic Theory" Higgins says, "In my 'Comparative View' the term *ultimate particle* means the last division of elementary matter, and the term *molecule* the last division of a chemical compound." This is shown when he says, "As every ultimate molecule of nitre contains, most commonly, four ultimate particles of dephlogisticated air, and one of phlogisticated air...";[14] and again,[15] where speaking of nitrous air, he says, "Therefore every ultimate particle of phlogisticated air must be united to two of dephlogisticated air; and these molecules combined with fire

EXPERIMENTS

AND

OBSERVATIONS

ON THE

Atomic Theory,

AND

ELECTRICAL PHENOMENA.

BY

WILLIAM HIGGINS, Esq.

F.R.S. & M.R.I.A.

PROFESSOR OF CHEMISTRY TO THE DUBLIN SOCIETY.

LONDON:

PRINTED FOR LONGMAN, HURST, REES, ORME, AND BROWN.

1814.

FIGURE 2.—TITLE PAGE OF HIGGINS' "ATOMIC THEORY." THIS WORK CONSTITUTED HIS FORMAL CLAIM TO THE ATOMIC HYPOTHESIS

constitute nitrous air." The clear distinction between atom and molecule which will be noted in several other excerpts to follow was apparently unsatisfactory to Higgins for in a later definition of terms just cited he goes on to say[2] "....I now adopt for the latter the term *atom*, and for a more complicate compound that of *molecule*. This makes no difference in the system." Two years later[16] he defines an *atom* as a compound of two particles in every proportion, a *molecule* a compound of two atoms. These last definitions are less clear than his first. Perhaps he intentionally assigned to the word *atom* a meaning other than that assigned by Dalton.

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and Philosophical Society of Manchester," Second Series, 1805, Vol. I, pp. 244–58. Alembic Club Reprint, No. 2, Edinburgh, 1923.

[11] All page references which follow are to this work.

[12] DALTON, "A new system of chemical philosophy," Manchester, 1808.

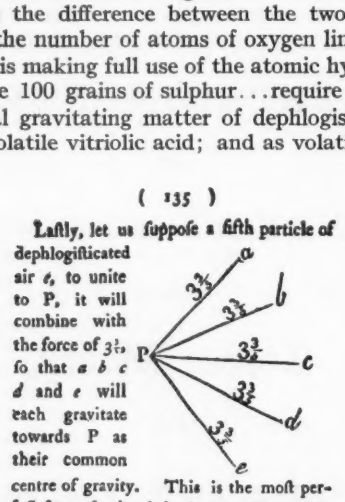
[13] Reference 4, p. 11.

[14] *Ibid.*, p. 123.

[15] *Ibid.*, p. 14.

[16] HIGGINS, *Phil. Mag.*, 48, 363, 408 (Nov., 1816).

When Higgins speaks of the ultimate particles possessing their individual weights, and when he clearly recognizes the difference between the two oxides of sulfur as the number of atoms of oxygen linked to the sulfur, he is making full use of the atomic hypothesis,[17] "Therefore 100 grains of sulphur. . . require 100 or 102 of the real gravitating matter of dephlogisticated air to form volatile vitriolic acid; and as volatile vitriolic


(135)

Laſtly, let us ſuppoſe a fifth particle of dephlogiſticated air *e*, to unite to P, it will combine with the force of $3\frac{3}{4}$, ſo that *a b c d* and *e* will each gravitate towards P as their common centre of gravity. This is the moſt perfect ſtate of colourleſs nitrous acid; and in my opinion no more dephlogiſticated air can unite to the phlogiſticated air, as having its whole force of attraction expended on the particles of dephlogiſticated air, *a b c d e*. This illuſtrates the nature of ſaturation. Thence we find that dephlogiſticated air is retained with leſs force in the perfect or colourleſs nitrous acid, than in the ſtraw-coloured, or in the red, or in nitrous air. This explains the eaſy ſeparation of dephlogiſticated air from perfect nitrous acid, when expoſed to the ſun, or even to an artificial light or heat, at the ſame time that the

K 4 nitrous

FIGURE 3.—DIAGRAM ILLUSTRATING THE HIGHEST OXIDE OF NITROGEN; IT IS PRECEDED BY SIMILAR DIAGRAMS CONTAINING FEWER OXYGEN ATOMS

acid is very little short of double the specific gravity of dephlogisticated air, we may conclude that the ultimate particles of sulphur and dephlogisticated air, contain equal quantities of solid matter; . . . Hence we may conclude, that, in volatile vitriolic acid, a single ultimate particle of sulphur is intimately united only to a single particle of dephlogisticated air; and that, in perfect vitriolic acid, every single particle of sulphur is united to 2 of dephlogisticated air, being the quantity necessary to saturation. . . . . As 2 cubic inches of light inflammable air require but 1 of dephlogisticated air to condense them, we must suppose that they contain equal number of divisions, and that the difference of their specific gravity depends chiefly on the size of their ultimate particles; or we must suppose that the ultimate particles of light inflammable air require 2 or 3, or more, of dephlogisticated air to saturate them. If this latter were the case, we might produce water in an intermediate state, as well as the vitriolic or the nitrous acid, which appears to be impossible; for in whatever proportion we mix our airs, or under whatsoever circumstance we combine them, the result is invariably the same. This likewise may be observed with respect to the decomposition of water. Hence we may justly conclude, that water is composed of molecules formed by the union of a single particle of dephlogisticated air to an ultimate particle of light inflammable air, and that they are incapable of uniting to a third particle of either of their constituent principles."[18]

This last excerpt indicates that Higgins realized that chemical combination takes place only by the union of atoms, and that the union involved definite numbers of atoms; the same holds for decomposition. Dalton's biographer, Henry, claims[3] that since Higgins assumed the oxide of sulfur to consist of an atom of sulfur and an atom of oxygen (because the weights of sulfur and oxygen were equal) he should go on to say that water was a compound of one atom of hydrogen and eight atoms of oxygen (presumably because the oxygen weighed eight times as much as the hydrogen). The justification of such a criticism is not clear. Higgins may well have realized that the atom of oxygen weighed eight times as much as one of hydrogen.

Speaking of nitrous gas, Higgins says,[19] "I likewise am of the opinion, that every primary particle of phlogisticated air is united to two of dephlogisticated air, and that these molecules are surrounded with one common atmosphere of fire." He then goes on to show that the difference between the oxides of nitrogen is in the number of oxygen atoms linked to the nitrogen atom.[20] "Let us suppose *P* to be an ultimate particle of phlogisticated air. . . . . Let *a* be a particle of dephlogisticated air. . . . . Let us suppose another particle of dephlogisticated air *b* to unite to *P*. . . . . This I consider to be the true state of nitrous air. Let us now suppose another particle of dephlogisticated air *c* to unite to *P*. . . . . such is the state of red nitrous vapor, or the red nitrous acid.

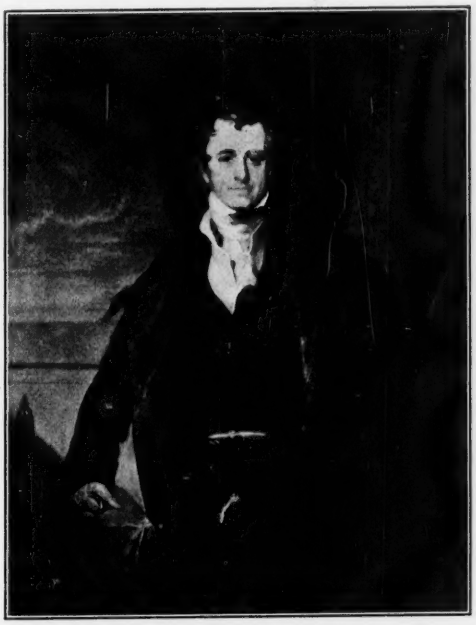
"Let us again suppose a fourth particle of dephlogisticated air *d* to combine with *P*, . . . this I think is the state of the pale or straw-colored nitrous acid. Lastly, let us suppose a fifth particle of dephlogisticated air *e*, to unite to *P*, . . . so that *a*, *b*, *c*, *d*, and *e* will each gravitate toward *P* as their common center of gravity. This is the most perfect state of colourless nitrous acid; and in my opinion no more dephlogisticated air can unite to the phlogisticated air, as having its whole force of attraction expended on the particles of dephlogisticated air, *a*, *b*, *c*, *d*, *e*. This illustrates the nature of saturation." This discussion is illustrated by means of diagrams (Figure 3). In his "Atomic Theory" Higgins quotes the above but supplies the more modern terms to the various oxides and acids. Henry has criticized the above by stating that, "Higgins'

[17] Reference 4, p. 36.

[18] *Ibid.*, p. 37.
[19] *Ibid.*, p. 132.
[20] *Ibid.*, pp. 133–5.

notion of the composition of the three last compounds of nitrogen and oxygen was purely conjectural, being supported by no experimental evidence whatever." This criticism, it seems to the author, is hardly appropriate today; for as we have mentioned before there is every indication that Higgins' approach to the atomic hypothesis involved considerably more experimental considerations than did Dalton's—and Henry himself says, "It would be unadvised to claim for Dalton a high station in experimental chemistry. He possessed neither the mental habits and tastes for extreme exactitude nor the unrivalled manual expertness which characterized Davy, Wollaston and Prout."[3]

The use of diagrams, with letters to represent the individual atoms, in itself necessitated a realization of the atomic hypothesis. Thus, "Let *A* be a particle of

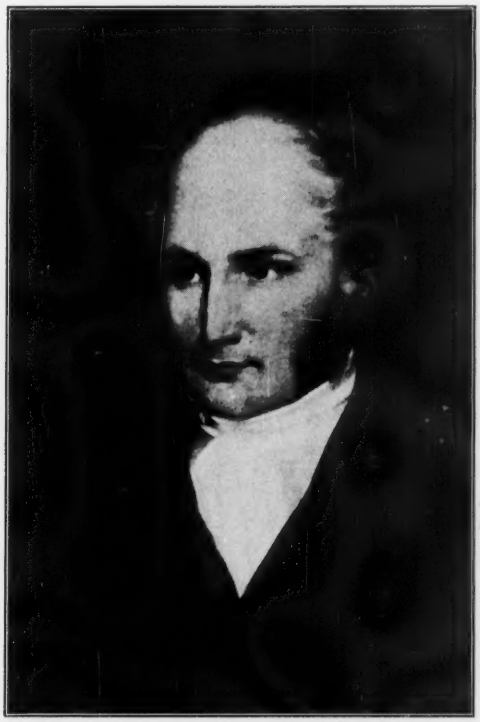


HUMPHRY DAVY

water and *I* and *D* its constituent principles; *I* inflammable air and *D* dephlogisticated air, combined with the force of $6^5/_8$";

$$I \overset{6^5/_8}{\frown} D^{21}$$

These diagrams show that Higgins attempted to assign a numerical value to affinity between the atoms, a task later attempted by many chemists without success. Chemical reaction took place only when the force which held the atoms together happened to be weaker than the force exhibited by some external atom for one of the atoms concerned: "Particularly when the above-mentioned force of *S* is constantly riveted or levelled, if I may use the expression, towards dephlogisticated air, in whatever compound, or in whatever state it meets with it, unless some other power counteracts it; and what can this be, but the union of the ultimate particles of sulphur to some other substance which attracts them more forcibly, or their own attachment to one another so as to form an aggregate?"[21] "When vitriolic acid, whether diluted or not, is mixed with oil, an ultimate particle of vitriolic acid influences with a



Courtesy of Dr. F. E. Clark

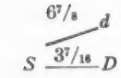
WILLIAM PROUT

certain force an ultimate particle of oil, while the latter attracts the vitriolic with the same force. The oil will not take *D d* from *S:*

but from the joint attraction of *S-D-d* to oil, they will approach with equal pace, and combine. Thus this mixture more than mechanically, but not quite chemically united, may be resolved into the different fluids mentioned above. The particle of oil will retain *D* or *d* and form fixable air; at the same time that *S* will retain *d* or *D* with its full force, and form volatile vitriolic acid."[22] "Let *S* be a particle of sulphur, *d* a particle of dephlogisticated air, which it attracts with the force of $6^7/_8$, and let the compound

[21] Reference 4, p. 45.

[22] *Ibid.*, p. 66.



be volatile sulphureous acid; here the tie between S and d is greater by $^2/_8$, than that between the constituent principles of water, which is but $6^5/_8$. As the attraction of bodies is mutual, let us suppose S to possess one-half this force, which is $3^7/_{16}$, and this to be its utmost exertion, and likewise d to possess the other half, which is $3^7/_{16}$ more, which will unite them with the above-mentioned force. Let us suppose another particle of dephlogisticated air D to have a tendency to

Courtesy of "Discovery of the Elements"
THOMAS THOMSON

unite to S, with the force of $3^7/_{16}$, in order to form perfect vitriolic acid: to receive D, S must relax its attraction for d one-half....."[23] "Let the two diagrams be molecules of concentrated vitriolic acid; which let us suppose influence each other..."[24]

Higgins believed that the use of numerical values for inter-atomic affinities would lead to more comprehensive views if studied by a mathematician. In polyatomic molecules he says, "I do not mean to intimate that these are their absolute forces; but, nearly the proportion they bear to one another."[25]

The attempt to use numerical values for the affinity between atoms may not be considered a success, but we feel sure that Higgins was quite familiar with the affinity which we today call valence. This affinity arose within the atoms themselves: "...And supposing sulphur to be a simple substance, whose ultimate particles attract dephlogisticated air with forces inherent in themselves...as an alkali does an acid..."[26] It was subject to outside forces, such as heat: "If mercury were a simple body, whose ultimate particles attract dephlogisticated air, but which, from their own influence on each other, cannot unite to it until this is counteracted by heat..."[27] "The constituent principles of nitre attached with the above force, will recede from each other when exposed to heat by the interposition of fire, whereby their union or mutual influence is weakened; and this diminution of the force of their attraction, is in a duplicate ratio to the squares of their distances. Metallic substances, having their ultimate particles likewise removed from each other when exposed to heat, by which their aggregate influence is diminished, attract dephlogisticated air with the greater force."[28] "It appears to me that solution....is occasioned by a sort of intermediate attraction, not differing from chemical attraction but in its degree of force, and not at all different from that power whereby the heavenly bodies influence one another."[29]

THE ORIGIN OF THE DALTON MYTH

If the atomic hypothesis was so clearly stated by Higgins, as is shown in the preceding section, an inquiry into the reasons for our current assignment of credit to Dalton is in order. The answer lies as White points out[7] in the extraordinary influence which Thomas Thomson exerted in favor of Dalton in his essays on the "Atomic Theory" in the "Encyclopedia Britannica"[30] and in his "System of Chemistry."[31] The bias of Thomson was quite obvious to his contemporaries; in 1854 Henry admits[3] that most chemical writers assign credit for the discovery to Higgins. Higgins was acknowledged in America, for Thomas Cooper, who revised and published Thomson's "System of Chemistry" at Philadelphia in 1818 includes a footnote which emphatically declares "the atomic theory was first stated and explained by Dr. Bryan Higgins[32] in 1789."[33]

It is not surprising to find that Higgins himself felt that Thomson was as much at fault as Dalton and his accusations of Dalton's plagiarism are somewhat tempered by the fact that the reader suspects that Thomson is the real culprit.

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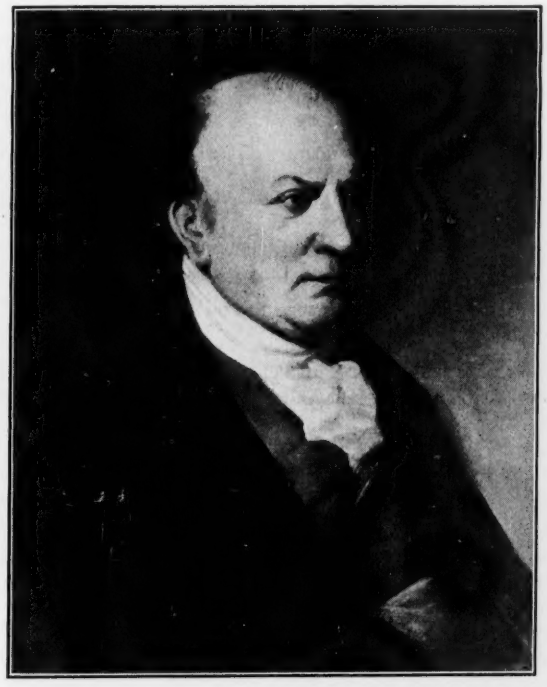
[23] Reference 4, p. 39.
[24] *Ibid.*, p. 271.
[25] *Ibid.*, p. 120.
[26] *Ibid.*, p. 35.
[27] *Ibid.*, p. 225.
[28] *Ibid.*, p. 105.
[29] *Ibid.*, p. 73.
[30] THOMSON, "Atomic theory" in the fourth and fifth editions of the "Encyclopedia Brittanica," Vol. I, Part 2.
[31] THOMSON, "System of chemistry," 3rd ed., Edinburgh, 1807, Vol. III, pp. 424–9, 451–2.
[32] Although Bryan Higgins is said to have preceded even William Higgins in considering the atomic hypothesis, there seems to be little doubt that Cooper means *William Higgins* in this case.
[33] SMITH, E. F., "Old chemistries," McGraw-Hill Book Co., New York City, 1927.

Berzelius, writing in the "Annals of Philosophy" for December, 1813, said, "As far as I know, the English philosopher, Mr. John Dalton, guided by the experiments of Bergman, Richter, Wenzel, Bertholett, Proust, and others, was the first person who endeavoured to establish that hypothesis.

"Sir Humphry Davy has lately assured us that Mr. Higgins, in a book, published in 1789, established the same hypothesis. I have not seen the work of Mr. Higgins, and can only notice the circumstance on the authority of Davy."

Thomson, editor of the *Annals*, appended the following footnote to the letter, "The work of Higgins on



From a painting by Charles Wilson Peale
THOMAS COOPER

phlogiston is certainly possessed of much merit; and anticipated some of the most striking subsequent discoveries. But when he wrote, metallic oxides were so little known, and so few exact analyses existed, that it was not possible to be acquainted with the grand fact that oxygen, etc., always unite in determinate proportions, which are multiples of the minimum proportion. The atomic theory was taught by Bergman, Cullen, Black, etc., just as far as it was by Higgins. The latter, indeed, states some striking facts respecting the gases, and anticipated Gay Lussac's theory of volumes; but Mr. Dalton first generalized the doctrine, and thought of determining the weight of atoms of bodies. He showed me his table of symbols, and the weight of six or eight bodies, in 1804; and I believe the same year explained the subject in London, in a course of lectures delivered in the Royal Institution. The subject could scarcely be broached sooner. But about the same time several other persons had been struck with the numbers in my table of metallic oxides, published in my Chemistry; and the doctrine would have certainly been stated by others, if Dalton had missed it."

This footnote was attacked from two sources. A Mr. John Nash, for some years a member of the Manchester Literary and Philosophical Society (of which Dalton was a member) took Thomson to task for his failure to acknowledge Higgins and enumerated the errors found in the footnote.[34] Higgins himself does this in his "Atomic Theory" where he says, "If Dr. Thomson thought so much of my work on phlogiston, as he, erroneously, is pleased to call it, why not take notice of it in his Chemistry? As a compiler he should not have passed it over. This curious note of his accounts for the omission. He wished to leave the work itself in

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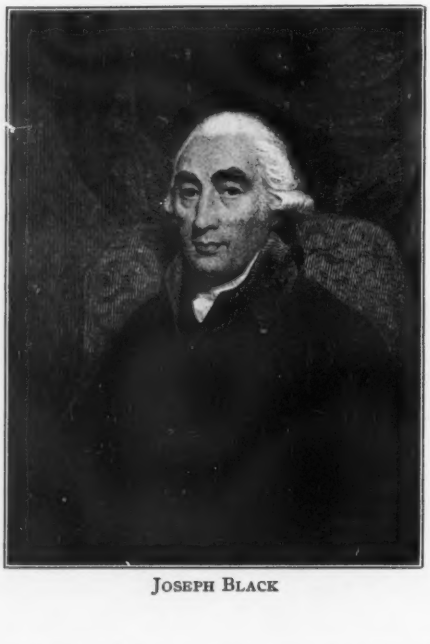
undisturbed oblivion; but whatever was valuable in it, he generously chose to bestow on Mr. Dalton."

He then points out that he was well acquainted with metallic oxides at the time he wrote the "Comparative View"; that there is no statement of the atomic hypothesis in the works of Bergman, Cullen, Black, and others; that he had applied the doctrine extensively

[34] NASH, *Phil. Mag.*, **43**, 54 (1814).

and that "it was founded on well-chosen facts and mathematical demonstrations, which Dalton omitted for reasons best known to himself"; and that when Thomson says, "The subject could scarcely be broached sooner" he exhibits prejudice and partiality.

Higgins proved quite capable of carrying on his own battle. His first charge of plagiarism was in the following paragraph in his "Atomic Theory," "I cannot



JOSEPH BLACK

with propriety or delicacy directly say that Mr. Dalton is a plagiarist, although appearances are against him. Probably he never read my book; yet it appears extraordinary that a person of Mr. Dalton's industry and learning should neglect one of the few works that were expressly written on the subject of theory. At the time it was published, there were one thousand copies of it sold, and it was the principal means of putting an end to the controversy already alluded to, which otherwise might not be determined for several years."

At this time (1814) Higgins' Irish wrath was still smouldering, for the paragraphs which follow indicate that he is willing to let Dalton escape with but the suspicion of having attempted to do a crude job of revising Higgins' ideas. "I have read Mr. Dalton's 'New System of Chemical Philosophy,' as he calls it, with great attention; and also my 'Comparative View,' for the first time the last twenty years, and I cannot discover any improvements made in my doctrine, except what might reasonably be expected from any ingenious compiler, who had carefully perused my book.

"The atomic doctrine has been applied by me in abstruse and difficult researches. Its application by Mr. Dalton has been in a general and popular way, and it is from these circumstances alone that it gained the name of Dalton's Theory. Mr. Dalton's work is read; mine has been laid aside as soon as the controversy, which gave rise to it, ceased; and at that time the theory in question was not understood, nor did I expect it would for a considerable time. I calculated upon

Courtesy of "Discovery of the Elements"

JÖNS JACOB BERZELIUS

the middle of the present century. Probably it would have lain by since if it had not been for the genius and industry of Mr. Dalton." His reasons for opening the discussion are to combat "flippancy and manoeuvre." "The respect which I feel for truth and justice, rather than ambition for fame, induced me to undertake this task. The grateful acknowledgment of the public is all the reward men of science expect; and should they be liable to be stripped of that feather, through flippancy and manoeuvre, the grand object must be frustrated; men of true science will quit the field in disgust; and many will be deterred from entering into it, to the great injury of science."

Two years later Higgins published his last statements on the matter in a long letter to the editor of the *Philosophical Magazine*[13] and there is little doubt that he then felt that it was Thomson who had cheated him of his just deserts. During this controversy Dalton had remained silent while, as Higgins says, "Dr. Thomson steps forward as the advocate of Mr. Dalton, while he himself stands trembling and silent at the bar of justice.

"Had Dr. Thomson been a faithful and unprejudiced historian, he would have had the candour to mention my 'Comparative View' and the discovery of the atomic theory, before he brought forward the labours of Richter, which were subsequent to mine. . . . . And many misrepresentations are brought forward, in order to prepare the way for his ingenious friend to take possession of the Atomic System. . . . . the Doctor acknowledges . . . . that I anticipated Gay Lussac's theory of volumes. *What a boon!* yet the Doctor never

mentioned my name in the whole history of the Atomic Theory. This last circumstance shows a personal and rooted prejudice. It manifests in the most decisive manner a determined and wilful neglect, or rather suppression of previous labours."

Higgins let no opportunity pass to call attention to Thomson's errors. The latter had remarked[35] in discussing the charge that Dalton was familiar with Higgins' "Comparative View," "I put the question soon afterwards both to Dr. Henry and Mr. Dalton, and both of them assured me they never saw the book." To this Higgins replies,[13] "Now Dr. Henry published his 'Epitome of Chemistry' in 1801, long before Dalton laid hold of my Atomic Theory; and he quotes from my 'Comparative View' . . . . . How will the Doctor get over this? What could be his motive to advance such an erroneous statement? It was evidently to defend Dalton against the suspicion of plagiarism: for he was aware, if Henry should be known to be acquainted with the work, that Dalton his neighbor and intimate friend could not be a stranger to it. . . . . What inconsistency! What prevarication!"

It is interesting to note that the original exposition of Dalton's ideas by Thomson was based on a few minutes' conversation and a brief written memorandum which Dalton had given Thomson. The latter admits this in a footnote in his "System of Chemistry." From this slight acquaintance with the subject grew the Dalton myth.

Whether or not the belief of Higgins and others that Dalton actually was familiar with the "Comparative View" at the time he enunciated his atomic hypothesis is justifiable is difficult to ascertain. Henry, in his "Life of Dalton"[3] states, "I have heard my father affirm, on various occasions, and to various persons, that Dalton had never seen Mr. Higgins' work till some years subsequently to the publication of the 'New System,' when it was lent to him by my father." He then cites other evidence of this sort and finally states, "This testimony is conclusive. It would be superfluous to those who were personally acquainted with Dalton, and who knew closely his mental habitudes and modes of study. It was never his practice to devote much of his time to reading."

Courtesy of "Discovery of the Elements"

TORBERN BERGMAN

We have no direct evidence to show that Dalton was an outright plagiarist. It matters not for this discussion; it has been the author's intent only to demonstrate that William Higgins was the first to introduce the atomic hypothesis to chemistry. Whether or not the author has been successful is, as Higgins put it, "not confined to the decision of a few individuals, but is laid before a grand tribunal and it rests with them to give a verdict."

[35] THOMSON, *Ann. Phil.*, **4**, 52–66 (1814).

A HIGH-SCHOOL COURSE *in* CHEMISTRY WHICH DOES NOT LEAD *to* REPETITION *in* COLLEGE[1]

P. M. GLASOE

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THE present high-school course in chemistry is open to the double indictment that

(1) It does not prepare for college or university: it is accepted as a credit for entrance, but students with this credit are not admitted to advanced work in chemistry.

[1] Presented before the Division of Chemical Education at the ninety-fifth meeting of the A. C. S., Dallas, Texas, April 21, 1938.

(2) It does not prepare for life. The high-school course in chemistry, today, is a paragraph by paragraph, chapter by chapter, miniature, college first-year course. It deals with a myriad of facts, three-quarters of which are forgotten in a year following the course.[2] It is far too technical and spends too much time in memorizing the host of facts necessary for passing the examination, usually imposed by a higher examining authority than the high-school teacher. It leads to nothing else than a college first-year course which is a detailed repetition of the work done in high school. The latter degenerates into a process of cramming in an effort to fortify the pupils against the impending college entrance examination. Cramming mills—politely called "coaching schools"—are operated by experts who have developed a technic for memorizing the vast array of facts that will be required during the college entrance examinations.

A study of the examination questions[3] given by the college entrance authorities reveals the fact that over ninety per cent. of them are memory questions, instead of involving thought and reasoning.

No doubt every State Board of Education or other supervising authority has had high ideals in view when they outlined the course of study for the students of chemistry in their states. Here are some of the guiding principles which the State Board of Minnesota had in mind when the course was outlined.

(1) A thorough knowledge of elementary chemistry as such knowledge relates itself to good citizenship, social welfare, home and community life, commerce, the trades, and professions.

(2) An understanding of the interrelation of all sciences, thus giving a broader appreciation and understanding of the world in which we live.

(3) Training in scientific observation and thinking, leading to the ability to make impartial comparisons and careful generalizations upon a sound factual basis.

(4) Vocational information which will assist a pupil to determine whether chemistry offers him a field for his lifework.

(5) Chemical knowledge which will contribute to individual and community health.

(6) Interests which may function in a more worthy use of leisure time.

All of which is "a consummation devoutly to be wished." It is to be feared, however, that with eight hundred pages of text to be memorized in order to be ready to pass the threatening examination, the cultural, social, vocational, health, and other laudable implications, get slight attention. Much as we would like to have our high-school students emerge from their course thus equipped, we know that such ideals are impossible of attainment. No doubt they are justified under the plea that "not failure but low aim is crime."

The fact of the matter is, high-school textbooks are cyclopedias of technical, chemical facts instead of being guides to a cultural understanding of what chemistry is and what it does. Boys and girls can get a much more sympathetic understanding of chemistry through knowledge of how it deals with their problems of breathing, eating and digesting their food, the way their clothing and shelter are provided, and the way it contributes to health and happiness than through the learning, for temporary purposes, of a thousand more or less unrelated facts.

Hunter[4] claims that chemistry and physics have not held their own in the enrolment of high-school students. In thirty-eight years the percentage of chemistry students has been reduced from 9.62 to 7.31. In the face of the "very urgent boosting" of chemistry by the American Chemical Society and the interest aroused as a result of war propaganda, this is a disconcerting fact and one that must be explained from the inside. Hunter goes farther and shows that physics, in the same time, has dropped from an enrolment per cent. of 31.36 to 7.13; that the courses in physics and chemistry are rigidly static and have changed but little from the days of the Committee of Ten (1893); that these rigid courses consist of "the factual material and laws which college professors deem necessary as a basis for further achievement in college." (Let it be parenthetically remarked that after the high-school student has mastered this course, the college textbook and the college first-year course in physics blandly ignore the whole matter and proceed on the supposition that the freshman knows little or nothing about physics.)

Faint criticisms have often enough been raised against the miniature college first-year course given in high school. There is something radically wrong, a confession of impoverishment—when the college student shall be forced to retrace his high-school chemistry or physics course from A to Z, with only a few more trimmings added.

The better the high-school teaching is, the more disastrous is the college procedure. A correspondent writes me, "I teach high-school chemistry; my college freshmen habitually return to tell me in great glee that they 'never had to crack a book' in freshman chemistry. They think it a compliment to my teaching; I know it to be merely a sad reflection on the way our colleges do things. What high-school teacher could not tell most of the colleges of the ruin they have caused in killing the interest of young embryo chemists who are alert, chemists 'on the mark, ready set,' and where the college should crack the gun of 'go'—they listen in vain without hearing so much as the click of the hammer."

It is said that the Committee on Chemical Education of the American Chemical Society had "thirty thousand criticisms and suggestions from chemistry teachers, when the question of a Standard Minimum Course of High-School Chemistry" was being considered, and yet their proposed course deviates only very slightly, if at all, from the eight-hundred page

[2] POWERS, S. R., J. CHEM. EDUC., 2, 174 (1925).
[3] RICH, S. G., *ibid.*, 2, 142 (1925).
[4] HUNTER, G. W., "Science teaching," American Book Co., New York City, 1934, p. 149.

texts now on the market. It is further proof of the hold which the "college entrance" idea has on both college and high-school teaching staffs. The question is not, shall high-school chemistry prepare for life, but shall it prepare for entering college? And that, in the face of the fact that colleges refuse to accept the high-school course as preparatory to advanced work, and the additional striking fact that only a very small per cent. of high-school students continue physics and chemistry for any purpose whatever in college.

Now and then some individual teacher breaks through the age-old traditions and with a stroke of genius brings out an experiment in humanized science that sets communities agog; one that has for its objectives that of interesting and teaching live boys and girls the intensely practical physics and chemistry of living.

Such a case is now developing in St. Cloud, Minnesota, under Mr. O. A. Nelson. Since he introduced his glorified course in physics in 1936 the enrolment jumped from twenty-four to one hundred eighty-seven—an increase of seven hundred eighty per cent. A special physics course for girls is given, and here, too, registration rose from six to ninety-three in the same time—an increase of 1550 per cent. It is passing strange that it should be so difficult to change the ideal from that of preparing for college, according to the set notions of almost fifty years ago, to that of teaching the physics and chemistry of living.

We are prepared to meet, here, the age-old argument that to teach what chemistry is: what it has done, is doing, and will do, you must have a thorough foundation in the elements of chemical knowledge, such as is supposed to be given in the eight hundred pages of our high-school texts of today. Biology has not set up such a rigid requirement for the pursuit of its course. The pupils study flowers, plants, animals, and man without stressing the "life principle" at all; they deal with cells, cell growth, and multiplication without the faintest idea that they are here concerned with the most complicated chemistry in existence, without even knowing what kind of molecules make up the cell or how they work. Progress has been made both in teaching and textbook writing in the field of biology. Physics and chemistry texts and teaching have been static. The stream of life is passing over and around them with the results as shown: physics has gone down from 31.36 to 7.13 per cent.; chemistry from 9.62 to 7.31 per cent.

This is an educational democracy. High-school youth are declaring a protest against the too formal, too technical, and uninteresting courses in high-school physics and chemistry. They want to live by the way, and so they choose subjects that offer human interest as a part of their substance.

In his highly entertaining and instructive "Letters of a Self-Made Merchant to His Son," the honored editor of the *Saturday Evening Post*, tells of a young man who was thick as thieves with all the Greek philosophers and could read the poets in the original, but when he got out of college he couldn't sell an insurance policy nor could he "go on the road." He tried job after job and lost each in turn. Finally he got a position to teach Greek and Latin in a boys' school, but he forgot completely that he was teaching dead languages to live boys and so he was out of a job again.

A high-school course of today that has remained largely static since the "Committee of Ten" must come dangerously near the charge of trying to teach dead chemistry and physics to live boys and girls—the reaction is *they refuse to take it.*

We who have been in the business of teaching college chemistry since the days antedating the Committee of Ten have worked up a defence mechanism which sounds like this "I don't believe in a superficial course in chemistry that may so easily degenerate into a snap course about chemistry. I believe in teaching the fundamentals and teaching them thoroughly, so that the student shall have something to build on in after life."

The trouble with that whole proposition is that while we teach those fundamentals, we load them down with so much scientific verbiage, so many principles and applications that the whole business becomes a memory rigmarole, most of which is unessential, impractical, and highly theoretical. We object to superficiality but we are very well satisfied to talk about the Avogadro number, about the Law of Mass Action and equilibrium, about the details of normal, molar, and standard solutions, about ionization and osmotic pressure, just as if the average high-school student's life depended on it. We deal with atoms and molecules, millions of millions of millions of them; we speak of the kinetic energy of molecules and of the way they collide, as if it really meant something to us—as if we really understand what we are talking about—which, of course, we don't. We teach about chemical affinity and chemical energy as if we knew all about them; just as physicists and astronomers play hide and seek with gravity and magnetism. I tell my students that sodium unites with chlorine because sodium is electrically plus and chlorine is electrically minus. But do they? Are they? And why?

No, there is so much superficiality about our teaching of fundamentals that we may well shear away a lot more and probably leave the students with a few material concepts which they can take with them as illustrations of what chemistry is and equally as much what it is not.

We teach economics without insisting on a thorough mastery of theoretical statistics and higher mathematics; it is possible to give a live course in sociology without knowing all about the secret sins of society, the complicated chemical cures for social diseases, or the intricate laws of eugenics; we study the German language without knowing how many other languages have words like *vater* and *mutter* and without knowing why *die, der,* and *das* have come to be used as they now are; we study arithmetic without knowing the algebraic reason underlying our rules for square and cube root.

The same applies to chemistry. You don't have to

teach the solution of problems under Boyle's and Charles' laws in order to understand that when the air in the furnace is heated it rises, or that it takes many strokes of a pump to inflate a tire. Every intelligent boy and girl of today knows that while the tire remains the same size the amount and pressure of air in it varies directly with the number of strokes of the pump; also that the volume of the air in the pump varies inversely with the pressure upon the piston.

You don't have to teach how to balance oxidation reactions by the electronic method in order to understand that ammonia is formed in soil decomposition of organic matter and that oxidation plays an enormously important rôle in our bodies and in the manufacture of sulfuric and nitric acids, as well as in the reaction going on in the home furnace. The professional chemist should understand as much as possible about the nitration of cellulose, the manufacture of T.N.T. and the formula of a hundred dyes; the intelligent high-school boy can easily understand the formation of celluloid, bakelite, smokeless powder, and rayon—yes, he can go pretty nearly as far as the professional himself.

We boast of the scientific method and aspire to give our students the scientific spirit; but what are we to conclude when we are confronted with the cold fact that ninety out of every hundred questions asked in college entrance examinations are memory questions instead of requiring thought and reasoning? We sing in an age-old hymn, "'Tis all in vain that you profess the doctrines of the Church, unless you live according to your creed." That principle should apply in chemistry. If we believe in the scientific method and pretend to teach it or according to it, why don't we give our students a chance to show, in how far they have profited by it, by giving them scientifically formed questions, involving thought and reason?

But—I hear some one say—how are we going to spend one hundred eighty hours teaching high-school chemistry if we are not to be permitted to teach the atomic weights and atomic numbers of some twenty-five or thirty elements, their valences, and their myriad combinations? How about having to leave out atomic structure, equation writing, electron balancing, reactions for making sulfuric and nitric acids, phosphine, superphosphate, Haber's and Ostwald's ammonia processes; the full explanation of the Birkeland-Eyde, the LeBlanc and Solvay processes; the use of the cyclotron, and so forth?

It does look like a revolution, to be sure. All the subjects mentioned are essential for chemistry majors, for pre-medics, pre-engineers, and many other professions. But, remember, the great majority of your high-school students are not going to be chemists; they will not even go to college. Besides, your college first-year course will take care of that; it repeats all the substance of the present high-school course anyway. The new procedure would give the high school an excellent chance to teach its boys and girls a great deal of chemistry that will be of value to them throughout life.

A SUGGESTION FOR THE NEW PROCEDURE

Suppose we begin by calling the students' attention to the fact that they know a good many chemical data already, that is, the souring of milk, the properties of vinegar, fruit juices, and so forth; the "sweetening" of sour milk with soda, the electrolyte of their car battery; the action of soap, the use of baking powder, baking soda, fermentation in home-made apple cider, root beer, and the like. They know the names of a dozen or more common metals and a number of alloys—you don't have to teach these to them; you need only remind them, and if you treat each of the facts mentioned above you have already made a good start in humanized chemistry.

From here on you can build on their general science course, recalling, in review, every fact they once have learned. The atmosphere makes a good starting point. Burning, as an introduction to oxidation, brings up the formation of water. Then follow breathing and oxidation in the animal body; the formation of carbon dioxide; the exchange of this gas for oxygen in the lungs. As soon as you mention carbon dioxide it opens the whole field of coal, its formation, its uses, its products, its conservation, and waste. But you are far from having done with the atmosphere: the whole problem of ventilation, moisture content, physiological influence of carbon dioxide, resuscitation, pulmotors, oxygen administration in cases of lung disease; first aid for the drowning. A host of side lines of acute interest to daily living suggest themselves.

Right at this point the Weather Bureau may be studied. Here is an excellent place for the introduction of an intensely practical use of the scientific method. What is the Weather Bureau? Where are its stations? Who are the observers? How does an observer spend his time? What are low pressure areas? High pressure areas? What are trade winds? What are tornadoes? What is a whirlwind? Will it interest boys and girls to know that the air resting on one acre of ground weighs 44,000 tons? They will cease wondering about the power of a tornado when they know that the air on one square foot weighs a ton and when you put this air into motion, forty, sixty, seventy-five miles per hour, you get a momentum of terrific destructive force.

All that has to do with the atmosphere, and we are by no means through. There is romance in the discovery of helium in the sun years before it was found on the earth; and in how helium helped to solve the problem of radium and of the triumph of filling a fleet of Hindenburgs of six million cubic feet capacity each with what was once, and still is, a rare gas constituent of the atmosphere.

There is no damage done by calling attention to the romance of chemistry; there is lots of it. By a balanced welding of the romance with the pragmatism of chemistry you can make a subject that will keep boys and girls "on their toes" in pursuit of more and more knowledge about what makes up the life interests of intelligent human beings. An impractical and highly

theoretical treatment for high-school youth will lead to ennui and sophistication; the pragmatic-romantic treatment keeps active the natural buoyancy of child interest in life and its varied problems. The reason so many young people act as if they are bored with education and which makes them seek their interests in extra-curricular affairs is that their interest in chemistry, mathematics, and language have been snuffed out by poor teaching and uninteresting methods of presentation.

APPROXIMATE SOLUTIONS *to* PROBLEMS INVOLVING *the* IDEAL GAS LAW

ALEXANDER CALANDRA

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THE usual course in general chemistry in colleges includes considerable work in the solution of problems. The writer has found that the use of calculating devices stimulates interest not only in the devices but also in the problems themselves. The writer presents several aids that are readily understood and easily used by college students for calculations involving the ideal gas law. The instructor who does not care to encourage his students in the use of these devices may find them useful in enabling him to rapidly check student calculations.

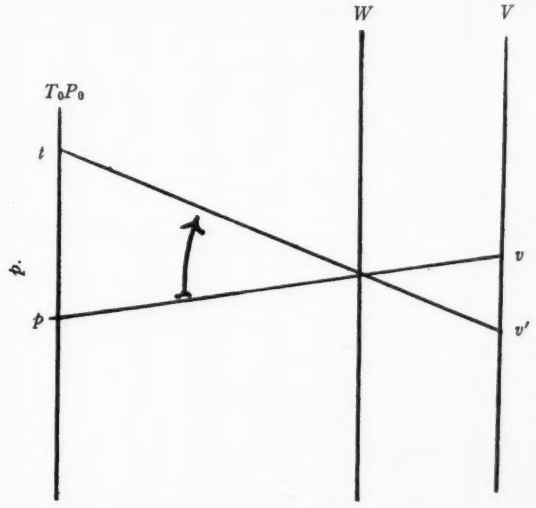

FIGURE 1

1. TABLES OF CORRECTED VOLUMES

Several of these are available. Lange's "Handbook of Chemistry"[1] contains a table which gives the factors necessary for the conversion of gas volumes to standard temperature and pressure. A useful modification of this table is the enclosed one which contains a correction for the vapor tension of water. The writer is indebted to Dr. Donald Decker Wright for the suggestion of compiling such a table; the work was done by Mr. Howard Nechamkin and the writer.

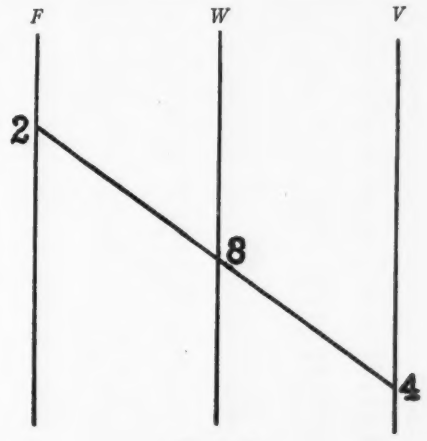

FIGURE 2

2. A SIMPLIFIED APPROXIMATE EQUATION

The following equation for converting volumes of gases to standard conditions has been derived by Homer E. Stavely.[2]

[1] LANGE, *editor*, "Handbook of chemistry," 3rd ed., Handbook Publishers, Inc., Sandusky, Ohio, 1939, p. 1245.

[2] STAVELY, "A simplified equation for converting volumes of gases to standard conditions," J. CHEM. EDUC., 11, 283 (1934).

$$V_0 = 0.9192 - [1.2(760-p) - 3(24-t)]10^{-3}$$

"V_0 is the volume of 1 cc. of gas at standard conditions measured at p mm. pressure and t degrees centigrade. This equation is most accurate from 18–25° and from 728 mm. to 755 mm."

3. A NOMOGRAPH

The following examples illustrate the use of a nomograph for solving gas law problems.

(*a*) Example: Given the volume v of a gas at a temperature t and a pressure p, to find the volume v' at S.T.P. Solution is indicated by Figure 1.

(*b*) Example: Given the volume v' of a gas at S.T.P., to find the volume v at a temperature t and a pressure p. Solution is indicated by the diagram if the direction of the arrow is reversed.

The problem of finding the volume v' of a gas at t' and p', when the original volume v at t and p is known, is solved by Method (*a*) followed by Method (*b*).

TABLE 1

TABLE FOR CORRECTION OF GAS VOLUMES MEASURED OVER WATER TO STANDARD CONDITIONS

Pressure (mm. of Hg)	Temperature (Centigrade) 10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
725	9086	9046	9006	8965	8924	8883	8842	8801	8758	8716	8674	8630	8587	8542	8498	8452
726	9099	9059	9018	8978	8937	8896	8855	8813	8770	8728	8686	8642	8599	8554	8510	8464
727	9111	9071	9031	8990	8949	8908	8867	8825	8783	8740	8698	8654	8611	8566	8522	8477
728	9124	9084	9043	9003	8961	8921	8880	8838	8795	8753	8710	8666	8624	8579	8534	8488
729	9137	9097	9056	9015	8974	8933	8892	8850	8807	8765	8723	8678	8636	8591	8546	8500
730	9150	9109	9069	9028	8986	8945	8905	8863	8820	8777	8735	8691	8648	8603	8558	8513
731	9162	9122	9081	9040	8999	8958	8917	8875	8832	8790	8747	8703	8660	8615	8570	8525
732	9175	9135	9094	9053	9012	8970	8929	8887	8845	8802	8760	8715	8672	8627	8582	8537
733	9188	9147	9106	9066	9024	8983	8942	8900	8857	8814	8772	8727	8684	8639	8594	8549
734	9200	9160	9119	9078	9037	8995	8954	8912	8869	8827	8784	8740	8697	8651	8607	8561
735	9213	9173	9132	9091	9049	9007	8967	8924	8882	8839	8796	8752	8709	8664	8619	8573
736	9226	9185	9144	9103	9062	9020	8979	8937	8894	8851	8809	8764	8721	8676	8631	8585
737	9239	9198	9157	9116	9074	9033	8991	8949	8906	8863	8821	8776	8733	8688	8643	8597
738	9251	9210	9169	9128	9087	9045	9004	8962	8919	8876	8833	8788	8745	8700	8655	8609
739	9264	9223	9182	9141	9099	9058	9016	8974	8931	8888	8845	8801	8757	8712	8667	8621
740	9277	9236	9195	9154	9112	9070	9029	8986	8943	8901	8858	8813	8770	8724	8679	8633
741	9289	9248	9207	9166	9124	9083	9041	8999	8956	8913	8870	8825	8782	8736	8691	8645
742	9302	9261	9220	9179	9137	9095	9054	9011	8968	8925	8882	8837	8794	8749	8703	8657
743	9315	9274	9232	9191	9149	9108	9066	9024	8980	8937	8894	8849	8806	8761	8715	8669
744	9327	9286	9245	9204	9162	9120	9078	9036	8993	8950	8907	8862	8818	8773	8728	8681
745	9340	9299	9258	9216	9174	9133	9091	9048	9005	8962	8919	8874	8831	8785	8740	8693
746	9353	9312	9270	9229	9187	9145	9103	9061	9017	8974	8931	8886	8843	8797	8752	8705
747	9365	9324	9283	9241	9195	9157	9116	9073	9030	8986	8944	8898	8855	8809	8764	8717
748	9378	9337	9295	9254	9212	9170	9128	9086	9042	8999	8956	8911	8867	8821	8776	8730
749	9391	9349	9308	9267	9224	9182	9141	9098	9054	9011	8968	8923	8879	8833	8788	8742
750	9404	9362	9321	9279	9237	9195	9153	9110	9067	9023	8980	8935	8891	8846	8800	8754
751	9416	9375	9333	9292	9249	9207	9165	9123	9079	9036	8992	8947	8904	8858	8812	8766
752	9429	9387	9346	9304	9262	9220	9178	9135	9091	9048	9005	8959	8916	8870	8824	8778
753	9442	9400	9359	9317	9274	9232	9190	9147	9104	9060	9017	8972	8928	8882	8836	8790
754	9454	9413	9371	9329	9287	9245	9203	9160	9116	9073	9029	8984	8940	8894	8848	8802
755	9467	9425	9384	9342	9300	9257	9215	9172	9129	9085	9041	8996	8952	8906	8861	8814
756	9480	9439	9396	9354	9312	9270	9228	9185	9141	9097	9054	9008	8965	8918	8873	8826
757	9493	9451	9409	9367	9325	9282	9240	9197	9153	9110	9066	9021	8977	8931	8885	8838
758	9505	9463	9421	9380	9337	9295	9253	9209	9166	9122	9078	9033	8989	8943	8897	8850
759	9518	9476	9434	9392	9350	9307	9265	9222	9178	9134	9091	9045	9001	8955	8909	8862
760	9530	9489	9447	9405	9362	9320	9277	9234	9190	9146	9103	9057	9013	8967	8921	8874
761	9543	9501	9459	9417	9375	9332	9290	9247	9203	9159	9115	9069	9025	8979	8933	8886
762	9556	9514	9472	9430	9387	9345	9302	9259	9215	9171	9127	9082	9038	8991	8945	8898
763	9569	9527	9485	9442	9400	9357	9315	9271	9227	9183	9140	9094	9050	9003	8957	8910
764	9581	9539	9497	9455	9412	9370	9327	9284	9240	9196	9152	9106	9062	9016	8969	8922
765	9594	9552	9510	9468	9425	9382	9339	9296	9252	9208	9164	9118	9074	9027	8981	8935
766	9604	9565	9522	9480	9437	9394	9352	9309	9264	9220	9176	9130	9086	9040	8994	8946
767	9619	9577	9535	9493	9450	9407	9364	9321	9277	9233	9189	9143	9098	9052	9005	8959
768	9632	9590	9547	9505	9462	9419	9377	9333	9289	9245	9201	9155	9111	9064	9018	8971
769	9645	9601	9560	9518	9475	9432	9390	9346	9301	9257	9213	9167	9123	9074	9030	8983
770	9657	9615	9573	9531	9487	9444	9401	9358	9314	9270	9226	9179	9135	9089	9042	8995
771	9669	9628	9585	9543	9500	9456	9414	9370	9326	9282	9238	9192	9147	9101	9054	9007
772	9682	9640	9598	9556	9512	9469	9426	9383	9338	9294	9250	9204	9160	9113	9066	9019
773	9695	9653	9611	9568	9525	9481	9439	9396	9351	9306	9262	9216	9172	9125	9079	9031
774	9708	9666	9623	9581	9537	9494	9451	9408	9363	9319	9275	9228	9184	9137	9091	9043
775	9720	9678	9636	9593	9550	9506	9463	9420	9375	9331	9287	9240	9196	9149	9103	9055
776	9733	9691	9648	9606	9562	9519	9476	9433	9388	9343	9299	9253	9208	9161	9115	9067
777	9746	9704	9661	9618	9575	9531	9488	9445	9400	9356	9311	9265	9220	9174	9127	9079
778	9758	9716	9674	9631	9587	9544	9501	9457	9412	9368	9324	9277	9233	9186	9139	9091
779	9771	9729	9686	9644	9600	9556	9513	9470	9425	9380	9336	9289	9245	9198	9151	9103
780	9784	9741	9699	9656	9612	9569	9526	9482	9437	9393	9348	9301	9257	9210	9163	9115
781	9796	9754	9711	9669	9625	9581	9538	9495	9449	9405	9361	9314	9269	9222	9175	9127

Interpolation in Table 1 is simplified by use of the equation

$$\Delta F = 12\Delta P - 44\Delta T$$

Thus the appropriate factor for 18.8° and 753.1 mm. is

$$F + \Delta F = 9104 + 12 \times 0.8 - 44 \times 0.1 = 9109.2$$

Volume at Standard Conditions = Volume Measured × Factor

Table gives values of 10.000 × Factor

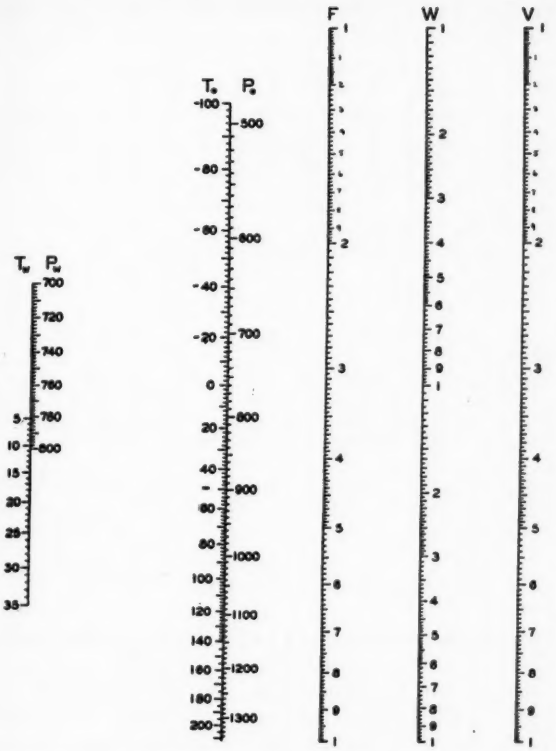

FIGURE 3.—A NOMOGRAPH FOR PROBLEMS INVOLVING THE IDEAL GAS LAW

In dealing with a gas collected over water, the student uses the P_wT_w instead of the P_0T_0 scale.

This same nomograph can also be used for rapid approximate multiplications and divisions.

When the V, W, and F scales are intersected by a straight edge, the scale values obtained will be related according to the equation

$$V \times F = W$$

Figure 2 shows how to perform the operations

$$2 \times 4 = 8 \text{ and } \frac{8}{4} = 2$$

The combination of two or more of the above processes make possible a number of rapid chemical calculations. The final results obtained by the use of this nomograph are accurate, at best, to about three parts in a thousand. Its chief value is in the checking of more accurate methods. If the final result is off-scale, the problem can usually be solved by multiplying one of the original values by 2, and dividing the final result by 2.

4. A SLIDE RULE

A slide rule for the simplification of gas calculation has been devised. It is adapted to engineering calculations.[3]

5. A GRAPHICAL SOLUTION

If a number of p-v curves for different temperatures are placed on one set of coördinates, it is possible to obtain direct solutions to a variety of gas problems. Such a device, although of pedagogic interest, is less convenient and accurate than the other methods described in this paper.

[3] MARX, "Slide rule simplifies gas calculations," *Chem. Met. Eng.*, 39, 556 (1932).

The NOSE *in the* CHEMISTRY LABORATORY

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THE most effective method of acquiring information on any subject is one which will permit the use of several senses. Those of us who study chemistry are fortunate in that we can use the sense of touch and smell as well as sight and sound. The sense of touch is developed in the manipulation of laboratory apparatus. The discrimination and identification of laboratory odors involve the use of the sense of smell. The chemistry student uses the sense of sight when he sees experiments performed by himself or others, reads his book or review outlines, writes examinations, works problems, or sees diagrams on the board. He uses his sense of hearing when he listens to lectures, discussions, and reports.

The nose is sensitive to incredibly small amounts of odorous materials and is probably more acute than the

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TABLE 1

	Bromine	Chlorine	Iodine	Hydrochloric acid	Nitric acid	Acetic acid	Benzene	Ethyl alcohol	Ether	Gasoline	Naphthalene	Phenol	Formaldehyde	Nitrobenzene	Carbon disulfide	Ammonium hydroxide	Pyridine	Hydrogen sulfide	Oil of wintergreen	Oil of cinnamon	Amyl acetate	Ethyl benzoate	Chloroform	Paraldehyde
Bromine	30	3	2	3	1	1			1							1								
Chlorine	2	18	1	1	10	4		2				1		1								1		2
Iodine	1		40																	1				
Hydrochloric acid	2	6		30		1								1							1		1	
Nitric acid	1	9	1		30																			1
Acetic acid		1	1	4	3	31							1									1		
Benzene							42																1	
Ethyl alcohol		1						34						2	1						3	1		
Ether									36			1	1									1	3	1
Gasoline								1		42														
Naphthalene											42			1										
Phenol						1			1			37											2	2
Formaldehyde	1	1		1				1	1				35								1			1
Nitrobenzene	1		1				2						3	30	1								1	3
Carbon disulfide				1				1					4		32				1			1	1	2
Ammonium hydroxide				3									2			38								
Pyridine																	43							
Hydrogen sulfide																		43						
Oil of wintergreen																			43					
Oil of cinnamon																				42			1	
Amyl acetate																					42			1
Ethyl benzoate								1						1								33	5	2
Chloroform		1					1	2								3						7	27	2
Paraldehyde	1							1	1			1	2	4	2							5	3	23

other senses. It is estimated that 2×10^{-11} milligrams or two hundred million molecules of mercaptan will stimulate the sense of smell. Many experiments in organic as well as inorganic chemistry involve materials with decided odors. Yet laboratory manuals and textbooks seldom refer to odors except to describe them as being "like rotten eggs," "pungent," "characteristic," "sharp," "offensive," "suffocating," "irritating," or "like rotten horseradish." In discussing the physical properties of elements or compounds mention is usually made of physical state, density, solubility, melting and freezing points, color, but rarely taste and odor. Odor or the lack of it is as characteristic a property of matter as is color or the lack of it. The eye is sensitive to slight changes in color. May we not expect the nose to be likewise sensitive to slight changes in odors?

An investigation of student response to odors would show if there were any value in placing more emphasis on this phase of the laboratory work. Do students recall odors? What is the explanation for inability to discriminate between odors? Among which odors is there the greatest amount of confusion? In an attempt to answer these questions an investigation of odorous substances was carried out with forty-three beginning students in chemistry.

Twenty-four small labeled bottles containing known odorous substances in the form of solids, liquids, and dissolved gases were given to each student to study and compare by means of cautious sniffing. On a mimeographed sheet containing the names of each substance the student recorded any descriptive words that came to his mind upon sniffing the substance. Approximately five hours were given to this study which should enable the student to associate name and odor to a fair degree. The student was then given the same twenty-four substances in the form of unknowns. Each bottle was covered with a paper jacket to prevent identification by appearance. An assistant held the bottle while the student sniffed the odor. The most likely name of the unknown substance was written on a slip of paper by the student who was permitted to consult his previously prepared mimeographed sheet containing descriptions of odors. This procedure was followed with each bottle in one-minute intervals. The results are recorded in Table 1. The horizontal column contains the names of the unknown substances given to the students. The vertical column contains names assigned to them by the students. An example to illustrate the use of the table is given: Ammonium hydroxide is called hydrochloric acid three times, formaldehyde twice, and ammonium hydroxide thirty-eight times.

The substances are arranged in order of ease of identification in Table 2.

TABLE 2

Pyridine
Hydrogen sulfide
Oil of wintergreen
Oil of cinnamon
Amyl acetate
Benzene
Iodine
Ammonium hydroxide
Phenol
Ether
Formaldehyde
Ethyl alcohol
Ethyl benzoate
Carbon disulfide
Acetic acid
Nitrobenzene
Bromine
Hydrochloric acid
Nitric acid
Chloroform
Paraldehyde
Chlorine

The compounds in the upper part of the series in Table 2 are probably true odors as distinguished from

the others which are irritants. The following excerpt is quoted from the Encyclopedia Britannica (Vol. 20, page 819, 14th Edition) under the heading "Two kinds of Response" to show that a difference exists between those substances called irritants and true odors.

"The lower portion of the nasal chamber is respiratory, and only its uppermost part is olfactory. Nevertheless, the whole surface of the chamber is in a way sensitive, for the fifth or trigeminal nerve is distributed throughout it. This nerve, once supposed to have to do with smell, is now definitely known to be concerned with irritants. If the olfactory nerve in a dog is destroyed, the animal will still sneeze when vapor of ammonia enters its nostrils. The same is true of human beings who through disease have lost the olfactory nerve but who still retain the trigeminal nerve. Many persons who fail to recognize the more delicate odors of flowers, food, and the like are nevertheless readily cognizant of even minute quantities of chlorine, ammonia, and other like substances. These materials are not odorous materials in the proper sense of the word but are irritants and affect the terminals of the fifth nerve, not those of the first nerve. True smell has to do with relatively delicate perfumes and odors and is mediated by the first nerve in contrast with irritants which stimulate the fifth nerve. It is of considerable importance in the study of olfaction to distinguish between these two nervous activities."

In an attempt to explain why some substances are more readily confused with others, it is well to point out that a difference exists between those substances that are nasal irritants and the true odors.

The acidic substances hydrochloric, nitric, and acetic acids and the halogens were confused among themselves and were among the most difficult materials to identify. These substances have an irritating effect on the nose. It is interesting to note that there is a marked difference in ease of identification of the halogens, the order being: iodine, bromine, and chlorine.

The first six substances in Table 2 were identified correctly by practically every one. These materials are true odors.

Five students were correct in all instances. The average number of mistakes in identification made by each was five. This reveals that students can correlate the identity of odors and substances to a rather high degree and that odors have a distinct memory value. A number of the compounds studied were unfamiliar, and it was necessary to learn new names as well as association between name and odor. A greatly extended period of study and comparison of odors beyond five hours would probably show better results.

BLACK COPPER *of* YUNNAN

H. BRUCE COLLIER[1]

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IT WAS a small ink-box in an antique shop that first attracted my attention. Its surface was a lustrous black, with a delicate pattern inlaid in silver, presenting a most striking appearance. Attracted by the beauty of this ware, which I learned was called *Wu T'ung* (black copper) and was manufactured in Yünnan Province (southwest China), I collected a number of pieces, not realizing until some time later that they presented a problem for the chemist.

Most of the articles made of this black copper are boxes for ink or tobacco (Figure 1), although pen holders, jewel cases, and even cigaret cases are occasionally seen. The designs are largely symbolic, but landscapes and inscriptions are also common. Around the sides of many of the ink-boxes are found depicted the "Four Friends," the plants representing the seasons—*prunus* for winter, orchid for spring, bamboo for summer, and chrysanthemum for autumn. That many of the boxes were made to order, as gifts, is indicated by the inscriptions or designs. Thus a very beautiful pair of oval ink-boxes (Figure 2) was evidently a graduation present, as the fish entering the Dragon Gate is symbolic of the student's attaining his official degree.

[1] Present address: MacDonald College, MacDonald College, Que., Canada.

One day the antique dealer brought an ink-box (Figure 3), the surface of which had been cleaned, with the result that most of the black had been removed and

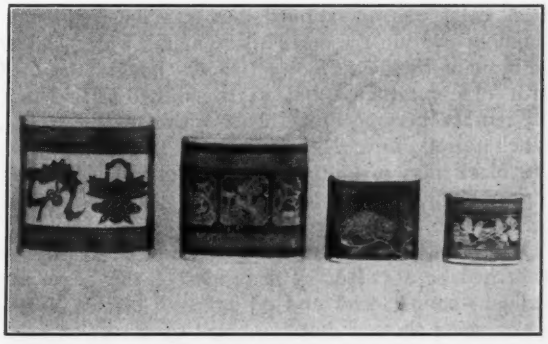

FIGURE 1.—TOBACCO BOXES (HEIGHTS 50, 42, 30, 24 MM., RESPECTIVELY). THESE ARE OVAL IN CROSS-SECTION. THE ONE ON THE LEFT IS INLAID WITH CONVENTIONAL DESIGNS. THE SECOND HAS THREE MINIATURE LANDSCAPE SCENES ON EACH SIDE, AND A LATTICE DESIGN ON THE COVER. THE THIRD IS ONE OF A PAIR, EACH HAVING TWO OF THE FOUR SEASONAL PLANTS ON ITS TWO SIDES. THE FOURTH IS ALSO ONE OF A PAIR WITH BIRD AND PLANT DESIGNS

the red color of metallic copper showed through. When I objected to the color the dealer explained that the black film would reappear in time, especially if the surface were rubbed with the hand. The dealer, when contact with silver wire, in an open dish of sodium hydroxide over the summer.

Shortly before I left China the antique dealer brought me a printed sheet, an announcement from one of the

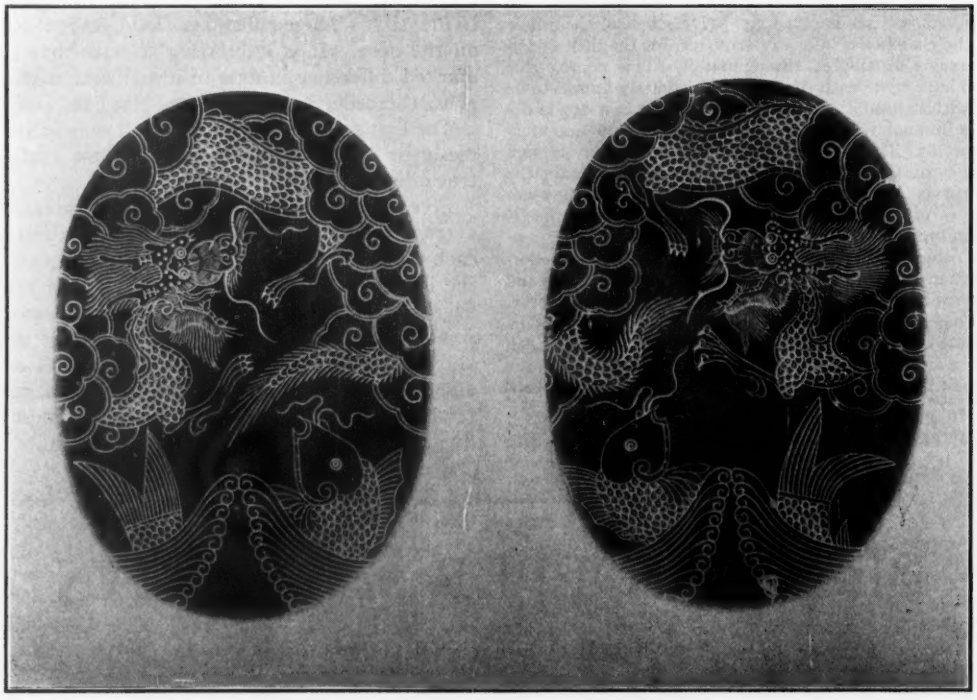

FIGURE 2.—INK-BOXES (LENGTH 80 MM.). AN EXCEPTIONALLY BEAUTIFUL PAIR OF BOXES, DESIGNED AS A GIFT TO A PERSON WHO HAS RECENTLY OBTAINED A DEGREE. ON THE SIDES ARE THE FOUR PLANTS REPRESENTING THE FOUR SEASONS: *Prunus* FOR WINTER, ORCHID FOR SPRING, BAMBOO FOR SUMMER, AND CHRYSANTHEMUM FOR AUTUMN (KNOWN AS THE "FOUR FRIENDS")

questioned on previous occasions, had insisted that the black color was not applied, but was the result of a "humour" within the pores of the metal, which had to be brought to the surface. I finally bought the box, with some misgivings, and was astonished to find that the surface became quite black within a few weeks. When a drop of ink fell upon another box on my desk, the black film instantly dissolved, exposing the red copper color. Fortunately this too turned black as before, with the passage of time.

The black film is extremely thin and can easily be scratched or abraded. The insides of the boxes are ordinary copper color and do not turn black. A few experiments showed that the black substance was unaffected by heating, but was readily soluble in dilute mineral acid. It would appear to be an oxide of copper, but the nature of its formation is a mystery. Attempts to obtain information regarding the process, or to secure samples of the ore were fruitless. However, I did succeed in producing a similar glossy black film on a strip of ordinary copper by immersing it, in

black copper manufacturers purporting to give information on the fabrication and use of *Wu T'ung*. I translated this, and the following is a summary of the points of interest.

YOH FU-HSING'S "WU T'UNG" SHOP

1. Any design can be produced—flowers and grasses, human figures, birds or animals, feathers and hair; landscapes, curios; characters or quotations—all exactly according to pattern.

2. The method of manufacture is as follows. First melt ordinary copper, then add gold, silver, iron, tin, and so forth, and the various chemicals. Afterward hammer into a plate and then engrave grooves and inlay the silver or gold wire. This "black copper" is not produced by applying a chemical after the completion of the article.

3. If the base is black copper, silver or gold wire is inlaid. If the base be gold or silver, a black copper pattern may be set in, and then gold or silver wire inlaid on this, if desired (Figure 1, left).

4. Upon completion the surface is red in color, and the pattern dull. Grasp the article firmly in the hand, so that the perspiration may soak into the surface. Within a day or two the copper will turn black. The color is quite permanent, the pattern clear and distinct, in all, a thing of beauty.

5. Acid perspiration will prevent the formation of the black

color. In order to obtain a good color and bright pattern, acid, greasy, or dirty substances must not be rubbed upon the surface. But if an article has been thus damaged it may be restored by cleaning the surface with an abrasive, when the perspiration of the hand will bring back the black color.

6. If the pattern or color is not very good, it may be improved by abrading the surface and re-forming the black film as described above. Only genuine *Wu T'ung* will turn black on contact with the perspiration of the hand. Imitation articles cannot be turned black in this manner, if they have once been rubbed red.

I was not surprised to find that the fundamental secret had not been divulged: the nature of the "various chemicals" had not been revealed. But I immediately performed the following experiment. I used an abrasive to remove a portion of the black film from one of my boxes. I then held it in the palm of my hand, at intervals, on a hot day, and within a few hours a deposit of black had been formed, with only a little of the reddish color of metallic copper showing through. At the same time there was a distinct green color of a copper compound left on my skin. Because of the apparent rôle of moisture, and the fact that it is only the silver-inlaid surfaces that turn black, is it possible that there is an electrolytic reaction, with an oxide of copper being formed on the surface of that metal?

It may be that the same material is found in Persia, for Janet Miller[2] says,

"We were shown candlesticks and Koran-boxes decorated by a secret process of inlaying with a black metal composition. It was very effective on the white silver. The skill and patience that had been expended in the execution of these articles were remarkable. The art of metal inlay is done superlatively well by the Persians and shows a high degree of technical achievement."

[2] MILLER, J., "Camel bells of Baghdad," Houghton Mifflin Co., Boston and New York City, 1934, p. 208.

FIGURE 3.—INK-BOX (LENGTH 110 MM.). DATED "YUNNAN, 1908." THIS BOX, WHEN PURCHASED, HAD BEEN CLEANED, AND THE REDDISH COLOR OF METALLIC COPPER SHOWED THROUGH. THE SURFACE BECAME PERFECTLY BLACK WITHIN A FEW MONTHS. ON THE SIDES IS A CONVENTIONAL DESIGN OF LATTICE, BATS, *Prunus*, AND BAMBOO

I am not aware that this black copper has been described before. Its beauty, together with the interesting chemical problem of its production, renders it worthy of a wider acquaintance.[3]

[3] This black alloy of copper would appear to be similar to that described by A. J. HOPKINS, ("Alchemy, child of Greek philosophy," Columbia University Press, New York City, 1934) which was used by the Egyptians as the basis for their alchemical processes. This alloy of copper, tin, lead, and iron was black on the surface. Is this evidence of a connection between ancient Egypt and China?

A NEW FEATURE

In the February issue of the JOURNAL OF CHEMICAL EDUCATION, a short section devoted to the interests of high-school chemistry will be inaugurated. Mr. Elbert C. Weaver, Instructor in Chemistry, Bulkeley High School, Hartford, Connecticut, and a member of the Division of Chemical Education Committee on High-School Chemistry, is to assist in editing this section. Mr. Weaver is spending the year, 1939–1940, as an exchange instructor at Polytechnic High School, Long Beach, California.

In this section will be found information concerning trends in the teaching of high-school chemistry, brief teaching and laboratory technics that have been found valuable, and reports of what various organizations interested in the teaching of high-school chemistry are doing. It is hoped that many high-school teachers will contribute to this section so that it may function as a valuable part of the JOURNAL.

Articles with a general relationship to introductory chemistry will continue to appear in the body of the JOURNAL.

Above all, let nothing distract thee. Do not strain and struggle, but maintain thy freedom and look things in the face as befits a man . . . a member of the state, and a mortal creature. And, among the principles which are ever most ready to hand for thee to turn to, let these two find a place: first, that things in themselves have no point of contact with the soul, but are stationed motionless without, while all unrest proceeds solely from the opinion within; second, that all the objects thou now beholdest will anon change and be no more. Think, and think often, how many changes thine own eyes have witnessed and know that the universe is mutation, and life opinion.—MARCUS AURELIUS

TEACHING PROBLEMS *in* PRESENTING *the* LAW *of* CHEMICAL EQUILIBRIUM *to* STUDENTS *in* ANALYTICAL CHEMISTRY

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INTRODUCTION

CHEMICAL equilibrium has become an important subject in the study of pure and applied chemistry. A knowledge of its principles is essential to the student for understanding the kinetics of chemical reactions in general as well as for furnishing a theoretical basis for separations in analytical chemistry. In fact, it has been said that one of the fundamental problems in theoretical chemistry is the study of equilibrium states. The growing importance of the subject is evidenced by the additional space given to it in recent texts on general chemistry, qualitative and quantitative analysis, and physical chemistry.

The subject of chemical equilibrium is usually introduced along with qualitative analysis, either during the second semester of the freshman year or the early part of the sophomore year. Freshmen and sophomores in general seem to have difficulty in understanding certain steps in the derivation of the Law of Chemical Equilibrium and its application to certain problems in analytical chemistry. Even seniors and graduate students, who have had the benefit of a more detailed treatment of chemical kinetics and equilibrium systems in general, often admit they still have difficulty with certain phases of the subject.

When one examines the various textbooks which present this subject to the beginning student the reasons for some of these difficulties seem to be apparent. The competition for space in most textbooks forces the authors to condense the treatment of this subject to a point where the student is left in a state of mental confusion. In other books the derivation of the equilibrium law is incomplete and frequently mathematically inaccurate, or based on implied assumptions not recognized by the student.

It is not the object of this paper to discuss the various applications of the law of chemical equilibrium or its limitations, but rather to point out some of the difficulties encountered in teaching its derivation to analytical students, to review some of the teaching approaches to these difficulties, and to present some of the author's explanations which he has found to be of value.

Since most freshmen are not familiar with the calculus, the derivation must be confined to algebra and the mathematics of variation. Moreover it is assumed in the following discussion that the general character of physical and chemical systems in equilibrium has been presented by the teacher; that the effects of concentration, temperature, and catalysts and the meaning of "rate of reaction" have been explained. The concepts of "activities" and "fugacities," and the expression of the equilibrium law in terms of mole fractions or partial pressures are purposely omitted. Owing to lack of space only generalized equilibrium equations will be presented. The teacher should illustrate these generalized equations with suitable examples. A certain amount of repetition of traditional presentations for illustrative purposes is unavoidable.

DERIVATION OF THE EQUILIBRIUM LAW

Let us start with a simple, bimolecular, homogeneous, chemical-equilibrium system involving unlike molecules in which one molecule of A reacts with one molecule of B to form one molecule of C and one molecule of D, expressed as follows:

$$A + B \rightleftarrows C + D$$

The rate[1] with which A reacts with B may depend upon (is a function "f" of) a number of independent variables which can be expressed as follows:

Rate forward is a function of concentration[2] of A, concentration of B, temperature, catalysts, nature of A, nature of B, nature of solvent or medium in which the reaction takes place, mechanism of the reaction; electrical and magnetic effects, light, energy of activation, and other factors.

[1] By rate we mean the number of moles of A or B reacting in unit time. Time is usually expressed in seconds. *Rate* of a reaction is also called *velocity* or *speed* of a reaction.

[2] The concentration of A means moles of A in a liter of the reaction mixture.

The velocity with which C reacts with D may also depend upon a similar number of factors, or

Rate backward is a function of concentration of C, concentration of D, temperature, catalysts, nature of C, nature of D, and the other factors mentioned above.

At equilibrium the forward and backward rates are equal, therefore *the two functions are equal* and we may say,

$$\frac{f(\text{Conc. } C, \text{ Conc. } D, \text{ temperature, catalysts, other factors})}{f(\text{Conc. } A, \text{ Conc. } B, \text{ temperature, catalysts, other factors})} = 1$$

When the temperature is constant it will be the same in both numerator and denominator; the effect of any catalysts on forward or backward rates will be the same, otherwise, a catalyst would shift the position of equilibrium and this does not happen. In general, the effect of all the other factors, excluding the concentration terms, may be considered constant in the ordinary study of this system. It is obvious, however, that the ratio of the concentration terms in both numerator and denominator will not, in general, be equal to 1. We may say, therefore,

Rate (forward) $= f[(A), (B)]$, all other factors constant[3]
Rate (backward) $= f[(C), (D)]$, all other factors constant

It is now important to know the relationship of these rates to the concentration terms. Guldberg and Waage enunciated this relationship in 1867 when they stated, "The rate of a chemical reaction is proportional to the active masses of the reacting substances present at that time." This is known as The Law of Mass Action, also called The Law of Molecular Concentration. They defined the term "active masses" as the molecular concentrations of the reacting substances. By concentration they meant *moles per unit volume.* From this law we may state with respect to the forward rate,

Rate$_f$[4] $\propto (A)$, when (B) and other factors are constant.
Rate$_f$ $\propto (B)$, when (A) and other factors are constant.

It may be difficult for the student to see how (B) remains constant in the above expression. Experimentally this would be difficult since it would necessitate adding B as fast as it reacted with A. However, unless (B) or (A) in the above expressions remains constant, the rates will not, in general, be directly proportional to their respective concentration terms. This point is stressed, since few texts that present the above step emphasize this fact, and the average student does not recognize the implied assumptions.

In actual practice both (A) and (B) usually vary simultaneously, so that many teachers do not present the above step but state that, since the rate varies *as the concentration of A* and *as the concentration of B*, it will vary *as the product of these concentrations* provided that all other factors that affect the velocity are constant, or

[3] Parentheses enclosing a term mean the *concentration* of that term.

[4] Rate$_f$ means rate forward.

Rate$_f$ $\propto (A) \times (B)$, therefore
Rate$_f$ $= K_1$[5] $(A) \times (B)$. Similar reasoning shows
Rate$_b$[6] $\propto (C) \times (D)$ therefore
Rate$_b$ $= K_2$[5] $(C) \times (D)$

At equilibrium, when the forward and backward rates are equal, the concentrations of A, B, C, and D remain constant and we have

$$\frac{(C) \times (D) \times K_2}{(A) \times (B) \times K_1} = 1, \text{ therefore}$$

$$\frac{(C) \times (D)}{(A) \times (B)} = \frac{K_1}{K_2} = K_e \text{ (equilibrium constant)}$$

The teacher then goes on to show that for the balanced general equation for chemical equilibrium systems, namely,

$$nA + mB \ldots\ldots \rightleftarrows oC + rD \ldots\ldots,$$

the equilibrium law specifies that

$$\frac{(C)^o \times (D)^r \ldots\ldots}{(A)^n \times (B)^m \ldots\ldots} = K_e$$

The above presentation introduces three teaching problems.[7]

(1) Why does the rate vary as the *product of the concentrations (other factors constant)*?

(2) Why do these products have to be raised to the *power of their respective coefficients?*

(3) What is the *physical significance of the constants*, K_1, K_2, K_e?

These questions will be taken up in the order named.

(1) THE VELOCITY VARIES AS THE PRODUCT OF THE CONCENTRATIONS.—In answering this question many teachers resort to analogies. For example, it is pointed out that the area of a rectangular field varies *as the length* and *as the width;* it will also vary as the *length times the width.* Many other analogies involving the concept of speed are used. Each teacher appears to have his own favorite analogy or approach in answering this question.

Belcher and Williams (*1*) have used the following apt analogy to explain this point.

"Suppose a hiker contacts an automobile at the rate of one each hour; then the chances for a ride are one each hour. If traffic speeds up so that he contacts ten automobiles each hour, then his chances for a ride are ten per hour. If nine more hikers join the first, then each of the ten hikers will contact each of the ten automobiles, or there will be 10×10 or 100 contacts or meetings per hour.

"But every meeting between hiker and automobile does not result in a ride. If one considers millions of such meetings it will be found that a constant fraction K (proportionality constant) of such meetings will result in a ride, or

Hikers $\times$ automobiles = meetings
Meetings $\times K$ = rides

"In a similar way a constant fraction K of the number of collisions of A molecules and B molecules will result in the formation of C and D, or

[5] K_1 and K_2 are known as *velocity proportionality constants* or *specific reaction rates.*

[6] Rate$_b$ means rate backward.

[7] Other problems such as an explanation of "Why is the concentration of a solid (and sometimes the liquid and gaseous solvent) in heterogeneous (and homogeneous) equilibrium systems considered constant?" could well have been added to the list which has been given.

$(A) \times (B)$ = chance of collision
Chance of collision $\times K$ = speed of reaction, or
$(A) \times (B) \times K$ = speed of forward reaction."

It has been the author's experience that, while many students may carelessly accept these analogies as satisfactory explanations, there are always a few who feel the analogies are irrelevant and they want a more rigorous proof. Of course, the teacher can avoid the issue by sending these students back to their mathematics to review the laws of variation and functions, and the meaning of the proportionality constant. Unfortunately, most mathematics books do not help the student much in this particular problem.

Another effective way, used by many teachers, of explaining the significance and meaning of this product $(A) \times (B)$ is the following.

Imagine two molecules of A and three of B in a container of definite volume (see Figure 1). Each A molecule has a chance of colliding and reacting with each

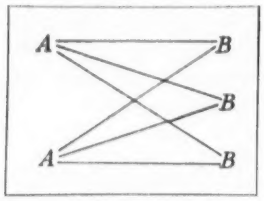

FIGURE 1

B molecule. Then two A molecules will have 2×3 or 6 chances of collision with the B molecules. If we double the concentration of the A molecules ($4A$), we will double the number of chances (12), of A molecules colliding with B molecules. While it does not necessarily follow that all of the collisions will be effective and result in a reaction, yet the number of molecules reacting will either be equal to or vary as the number of collisions if the temperature remains constant.[8] It also follows that the number of molecules of A and B will be proportional to their concentrations expressed, say, in moles per liter. We may state, therefore, that

Rate of A reacting with B $\propto$ number of collisions $\propto$
$2 \times 3 \propto (A) \times (B)$

Through the use of diagrams of this kind the number of possible collisions between any number of A and B molecules becomes apparent.

It is important to point out to the student that in the example given only collisions between *unlike* molecules result in a reaction, *i. e.*, collisions between the A molecules or between the B molecules are not counted since they do not lead to a reaction. Later we shall discover that the number of collisions between two *like molecules* that produce a reaction varies as their total concentration squared, and not as the product of their concentrations as in the case of the *unlike molecules above.*

The author has found the following proof of value in explaining why the velocity of the above reaction will vary as the product of the concentrations of A and B.

Let (A_i) be some concentration of A at the beginning of the reaction.
Let (B_i) be some concentration of B at the beginning.
Let (A_e) be some concentration of A after a time t or at equilibrium.
Let (B_e) be some concentration of B after a time t or at equilibrium.

Then it follows from the Law of Mass Action, if (A_i) changes to (A_e) and the (B_i) is held constant, that

$\frac{\text{Rate}_i}{\text{Rate}_x} = \frac{(A_i)}{(A_e)}$, when (B_i) and other factors are constant.
Rate_x = some intermediate rate between initial and final rates.

Now let (B_i) change to its final (B_e) while (A_e) is held constant, then

$\frac{\text{Rate}_x}{\text{Rate}_e} = \frac{(B_i)}{(B_e)}$, when (A_e) and other factors are constant.

Eliminating the intermediate rate (Rate_x) from the above two equations and rearranging terms, we have

$$\frac{(A_i) \times (B_i)}{\text{Rate}_i} = \frac{(A_e) \times (B_e)}{\text{Rate}_e} = \text{a constant} = \frac{1}{K}, \text{ then}$$
$$\text{Rate}_i = K(A_i) \times (B_i), \quad \text{or, generalizing,}$$
$$\text{Rate}_f \propto (A) \times (B)$$

Similar reasoning will show that

$$\text{Rate}_b \propto (C) \times (D)$$

(2) PROBLEM OF THE COEFFICIENTS.—When more than one molecule of A, B, C, and D are required to balance the equation, then certain additional difficulties in explanation are introduced. Thus, if

$$nA + mB \ldots \rightleftarrows oC + rD \ldots$$

then the problem is to show why the equilibrium law specifies that

$$\frac{(C)^o \times (D)^r \ldots}{(A)^n \times (B)^m \ldots} = K_e$$

Most authors of analytical texts either do not attempt to explain how this equation is derived or their attempts are inadequate and often misleading. It has been the author's experience that the difficulty which students have in applying the Equilibrium Law to certain types of problems originates from the fact that the derivation of the law itself was not made clear. The following examples illustrate typical presentations of this derivation. Consider the following equilibrium system

$$I_2 + H_2 \rightleftarrows 2HI$$

It is then pointed out that this equation may be rewritten in the following form

$$I_2 + H_2 \rightleftarrows HI + HI$$

[8] In some reactions (ionic and some molecular reactions) each collision appears to result in a reaction, while in others only a small fraction of the collisions result in a reaction. Effective collisions are those that produce a reaction.

Applying the Equilibrium Law to this equation we get

$$\frac{(HI) \times (HI)}{(I_2) \times (H_2)} = \frac{(HI)^2}{(I_2) \times (H_2)} = K_c$$

The student very naturally believes, from the above derivation, that $(HI)^2$ is one-half the total concentration of *HI* squared whereas it actually represents the total concentration of *HI* squared. When he is told this he is further confused by the following presentation: Let "*a*" equal the initial concentration of I_2, "*b*" equal the initial concentration of H_2, and "*x*" equal the amount of I_2 and H_2 which have reacted when equilibrium is attained, then

$$\frac{(2x)^2}{(a - x) \times (b - x)} = K_c$$

The student feels in this case that the concentration of *HI* is *both doubled and squared.*

The above derivations are therefore misleading and do not bring out the fact that the speed or rate of the above bimolecular reaction between *like molecules of HI* varies as the *total concentration* of the undissociated *HI* molecules *squared.*

Another method used quite generally by teachers (*2*) to make clear the use of coefficients in the general equilibrium equation is the combination of the separate equilibrium equations expressing the step-wise or bimolecular mechanism of the reaction. This method is effective and gives little trouble to the student, providing the real meaning of the separate concentration terms in the separate equilibrium equations is defined. Its weakness is that it does not enable the student to visualize the collision mechanism of the reaction and how this mechanism justifies the use of coefficients as powers in equilibrium equations. For example take the step-wise ionization of hydrogen sulfide, which may be represented as follows

$$H_2S \rightleftarrows H^+ + HS^- \quad \text{(primary ionization)}$$
$$HS^- \rightleftarrows H^+ + S^{--} \quad \text{(secondary ionization)}$$

Applying the Equilibrium Law to these two steps, we have

$$\frac{[9](H^+) \times (HS^-)}{(H_2S)} = K_1 = \text{primary ionization constant, and}$$
$$\frac{(H^+) \times (S^{--})}{(HS^-)} = K_2 = \text{secondary ionization constant.}$$

It is then pointed out that since the value of (HS^-) is common to and therefore the same for both expressions, we may eliminate it by multiplying the two equations, or

$$\frac{(H^+) \times (H^+) \times (S^{--})}{(H_2S)} = \frac{(H^+)^2 \times (S^{--})}{(H_2S)} = K_1 \times K_2 = K$$

Since the $(H^+)^2$ in this latter equation actually means (*3*) the total hydrogen-ion concentration squared, the student is confused. He reasons that since the primary ionization is greater than the secondary ionization then the value of (H^+) from the primary ionization is larger and different from the value of (H^+) from the secondary ionization; therefore the square of these terms should mean $(H^+)_p \times (H^+)_s$ which, of course, is not the total concentration of H^+ squared. The latter may be expressed as follows:

$$[(H^+)_p + (H^+)_s]^2 = (H^+)^2$$

This picture may be simplified if we consider the fact that the H_2S molecules, HS^-, S^{--} and H^+ ions are all present in equilibrium in the same solution. This means there can be but one concentration of hydrogen ion, or

$$H_2S \rightleftarrows \overset{H^+}{+}$$
$$HS^- \rightleftarrows H^+ + S^{--}$$

Therefore the (H^+) in both primary and secondary equilibrium equations is the same and represents the total concentration of H^+ in the equilibrium mixture.

It may also help to point out (*4*) that in the case of weak dibasic acids such as H_2S the secondary ionization takes place to a very small extent as compared to the primary ionization. It will therefore follow that the total concentration of H^+ will be practically equal to the concentration of HS^-, *i. e.*, practically all of the H^+ comes from the primary ionization. Using this approximation in the secondary ionization equilibrium equation we note that the concentration of the bivalent ion (S^{--}) is numerically equal to the secondary ionization constant.

The difficulty of the coefficients appears frequently in dealing with solubility product problems. For example, the solubility product of a saturated solution of $Mg(OH)_2$ is defined as

$$(Mg^{++}) \times (OH^-)^2 = K_{sp}$$

If the concentration of Mg^{++} and OH^- are required and the solubility product constant is given, the student is instructed to let $x = (Mg^{++})$ and $2x = (OH^-)$, then

$$x \times (2x)^2 = K_{sp}$$

Here again the student feels he has both *doubled* and *squared* the concentration of OH^-. It should be pointed out that $2x$ *is the total concentration of* OH^- and, as subsequently shown, the Mass Law requires that *this concentration be squared.*

The author has found the following approach to this general difficulty to be more easily understood by the student since it draws his attention to the important fact that the rate of a reaction between two *unlike* molecules, atoms, or ions varies as their product, whereas, if they are *alike*, it varies as their total concentration squared.

(1) Mechanism of the Reaction.

Several mechanisms for the general reaction

$$nA + mB \ldots . \rightleftarrows oC + rD$$

may be postulated:

(*a*) (1) Let *nA* molecules react to form one molecule of the polymer A_n, or

[9] The more recent texts have adopted the hydronium ion H_3O^+ instead of H^+.

$$nA \rightarrow A_n \qquad \text{(Equation 1)}$$

Since, as a rule, only two molecules collide at any instant (because the chance of a three-body collision is statistically improbable) we may imagine the formation of A_n to take place in bimolecular steps, or

$2A \rightarrow A_2$, then $A_2 + A \rightarrow A_3$ and so forth until A_n is formed.

(2) Let mB molecules react in a similar manner to form one molecule of the polymer B_m, or

$$mB \rightarrow B_m \qquad \text{(Equation 2)}$$

(3) Now let A_n react with B_m to form the product o molecules of C and r molecules of D, or

$$A_n + B_m \rightarrow oC + rD \qquad \text{(Equation 3)}$$

It is apparent that the sum of the three equations above gives us our original equation, namely,

$$nA + mB \rightleftarrows oC + rD$$

(*b*) If one objects to the assumption that the intermediate molecules A_n and B_m are formed we may assume the formation of intermediate compounds between A and B taking place in bimolecular steps, or

$$\begin{aligned} A + B &\rightarrow AB \\ AB + A &\rightarrow A_2B \\ A_2B + B &\rightarrow A_2B_2 \quad \text{and so forth, until } A_nB_m \text{ is formed, then} \\ A_nB_m &\rightleftarrows oC + rD \end{aligned}$$

The result will be the same as above.

(*c*) While it is statistically improbable, we may consider the simultaneous collision of nA molecules to form A_n and the simultaneous collision of mB molecules to form B_m, or the simultaneous collision of nA molecules and mB molecules to form the product. The mathematical treatment of these possibilities will lead to the same conclusion as above.

One of the inferences of the second law of thermodynamics is that for every possible mechanism of transformation of reactants A and B into the products C and D, there is a reverse mechanism. Any chemical equation which represents the forward reaction will, when read backwards, represent the reverse reaction. When equilibrium has been reached the rate in terms of a given mechanism will be equal to the rate of the reverse of this mechanism. This statement is often called the Principle of Detailed Balancing; it is also known as the Principle of Entire Equilibrium or of Microscopic Equilibrium (*5*).

(2) Derivation of General Equation.

Now in order to see how the Law of Mass Action applies to a chemical equilibrium involving more than one molecule of A, B, C, and D for the balanced equation, let us consider the reaction in terms of the mechanism postulated under (*c*) above.

Of the various ways of treating this problem the following one, expanded from a suggestion by Hogness and Johnson (*6*), seems to be the easiest for the student to follow. This treatment involves a study of the *chance of collision* between *like molecules*.

Case I

Let $n = 2$, then $2A \rightarrow A_2$; let $N = 5$ molecules of A; $N \propto (A)$.

Let us have, say, five molecules of A in a given container. The problem is to determine the number of chances of collision between any two ($=n$) molecules of A, not counting the same chance twice. $A1$ molecule (see Figure 2) will have four chances of collision with the other A molecules, namely, 1–2, 1–3, 1–4, and 1–5. $A2$ will have three further chances, namely, 2–3, 2–4, and 2–5. $A3$ will have two further chances, namely, 3–4 and 3–5. $A4$ will have one further chance, namely, 4–5. The total number of chances of two A molecules colliding will be $4 + 3 + 2 + 1$ or ten chances.

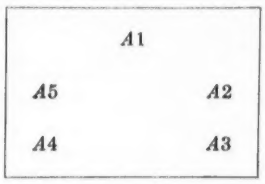

FIGURE 2

If N is the total number of molecules of A in the container (example, $N = 5$), the series which expresses the total number of chances of collision is $(N - 1) + (N - 2) \ldots\ldots + 1$. This sum may also be expressed by the formula $N(N - 1)/2$, or

$$(N - 1) + (N - 2) \ldots\ldots + 1 = \frac{N(N - 1)}{2}$$

We may say, therefore, that the total number of chances of any two A molecules colliding, when there are N molecules of A in the container, is $N(N - 1)/2$. It follows from this that the total number of chances of collision is proportional to $N(N - 1)$. (The proportionality constant $1/2$ establishes the equality of the above equation.)

In all actual experiments we are dealing with millions of molecules of A, so that N is always a very large number. This means that $(N - 1)$ is, for all practical purposes, equal to N. We may say, therefore,

Total number of chances of collisions $\propto N^2$.

Since N will be proportional to the concentration of A, expressed in moles per liter, we obtain the following relationship:

Rate of $2A$ forming $A_2 \propto$ number of chances of collision $\propto$ actual number of collisions $\propto N^2 \propto (A)^2$, then

Rate$_f = K_1(A)^2$, other factors constant.

Case II

Let $n = 3$, then $3A \rightarrow A_3$

If again we have five molecules of A in the given container and we consider the chance of collision of any three A molecules, not counting the same chance twice, the total number of collisions will be ten. They are (see Figure 2): 1–2–3, 1–2–4, 1–2–5, 2–3–4, 2–3–5,

3-4-5, 3-4-1, 4-5-1, 4-5-2, and 5-3-1. The mathematical formula which expresses the total number of chances of collision possible when three A molecules form A_3, and N molecules of A are present in the container, is:

Total number of chances of collision =

$$\frac{N(N-1)(N-2)}{6}, \text{ or}$$

Total number of chances of collision $\propto N(N-1)(N-2)$.

Since N is always a very large number $(N-1)$ and $(N-2)$ are nearly equal to N. Therefore, we may state

Total number of chances of collision $\propto N^3 \propto (A)^3$, or

Rate of $3A$ forming $A_3 \propto (A)^3$, therefore

$\text{Rate}_f = K_1(A)^3$.

Note: While N is always a very large number it is interesting to speculate on the condition in this system if we had but a few molecules of A present. In this case we cannot assume $(N-1)$ and $(N-2)$ to be nearly equal to N and the rate will not be proportional to N^3. This means that the Law of Mass Action is a statistical law, true in actual cases because we are dealing with a large number of molecules. Even under high vacuum conditions we still have billions of molecules per cubic centimeter.[10]

Case III

Let $n = 4$, or $4A \rightarrow A_4$.

If four A molecules collide to form one molecule of the polymer A_4, the mathematical formula which expresses the total number of chances of collision, when N molecules of A are present in the container is:

Total number of chances of collision =

$$\frac{N(N-1)(N-2)(N-3)}{24}, \text{ or}$$

Total number of chances of collision $\propto N^4 \propto (A)^4$.

Although the chance of a four-body collision is improbable, the mathematical treatment of this possibility leads to the same conclusion as if we considered the reaction to take place in bimolecular steps.

We are now able to generalize from the discussion above that when nA molecules react to form one molecule of the polymer A_n, and there are N molecules of A present, then

Total number of chances of collision =

$$\frac{N(N-1)(N-2)\ldots[N-(n-1)]}{\text{constant}}$$

Since there are "n" terms involving N in the numerator of this equation, therefore

Rate of nA forming $A_n \propto N^n \propto (A)^n$, other factors constant.[11]

This statement means that the velocity of a reaction between like molecules or ions will vary as the total concentration of these molecules or ions raised to the power of its respective coefficient in the balanced equation.

Now since we assumed the formation of the intermediate molecules A_n and B_m and when one molecule of each of these *unlike molecules* react they form the product, namely, o molecules of C and r molecules of D, it follows from our previous discussion (on *unlike molecules*) that

$\text{Rate}_f \propto (A_n) \times (B_m)$, other factors constant.

Since the number of collisions between nA molecules is proportional to $(A)^n$ and between mB molecules to $(B)^m$, then the number of collisions between nA molecules and mB molecules will be proportional to $(A)^n \times (B)^m$. Therefore

$\text{Rate}_f = K_1(A)^n \times (B)^m$

Similar reasoning will show that the velocity of the reverse reaction will be

$\text{Rate}_b = K_2(C)^o \times (D)^r$

At equilibrium when the two rates are equal, we have

$$\frac{(C)^o \times (D)^r}{(A)^n \times (B)^m} = \frac{K_1}{K_2} = K_e \quad \text{(equilibrium constant)}$$

This is a quantitative expression of the Law of Mass Action *under equilibrium conditions* and is called the Law of Chemical Equilibrium. It may be stated thus: *In any system in chemical equilibrium the product of the concentrations of the substances formed in the reaction, raised to the power of their respective coefficients, divided*

[10] Some apparently anomalous cases will be found among heterogeneous systems assumed to be in dynamic equilibrium involving such types as saturated solutions of difficultly soluble salts, solution pressures of the free elements, electrode potential systems, and vapor pressure of solids. For example, the average solubility-product constant of mercuric sulfide is about 1×10^{-52}. A simple calculation shows there are 10^{-3} ions each of mercury and sulfur per liter in equilibrium (?) with the solid phase mercuric sulfide. This really means there will be a mean probability of one ion of each in one thousand liters of water. The behavior of these ions becomes indeterminate and whether the statistical law of chemical equilibrium holds in these cases is very dubious. For a fuller discussion of this question, consult a paper by G. N. Lewis, entitled, "Generalized Thermodynamics Including the Theory of Fluctuations" (*J. Am. Chem. Soc.*, **53**, 2578-88 (1931)); see also G. N. Lewis and M. Randall, "Thermodynamics," McGraw-Hill Book Co., Inc., New York City, 1923, pp. 127-8.

[11] Kinetic formulas expressing the frequency of collisions between *unlike* and *like* molecules also confirm this conclusion (7). We learn, for example, that the number of collisions (Z_{AA}) between *like molecules* per cc. of a gas is given by the expression

$$Z_{AA} = \tfrac{1}{2}\sqrt{2}\,\sigma^2\pi u_A N_A^2$$

where σ is the effective diameter, N_A is the number of atoms or molecules per cubic centimeter and u_A the average velocity. When the temperature is constant in a given reaction all of the factors on the right of this equation but N_A^2 may be considered constant or

$$Z_{AA} \propto N_A^2$$

The number of collisions Z_{AB} between *unlike molecules* per cc. is given by the expression

$$Z_{AB} = 2\sqrt{2\pi}\, N_A N_B \left(\frac{\sigma_A + \sigma_B}{2}\right)^2 \sqrt{\frac{KT}{\mu}}$$

where N_A and N_B are the numbers of each kind of molecule or atom per cc., respectively, $\frac{\sigma_A + \sigma_B}{2}$ is the average effective diameter and μ is the reduced mass which equals $(m_A \times m_B)/(m_A + m_B)$ where m_A and m_B are the masses of the respective molecules. If the temperature is constant for a particular reaction involving unlike molecules then all the factors on the right of this equation but N_A and N_B may be considered constant, or

$$Z_{AB} \propto N_A \times N_B$$

by the product of the concentrations of the reactants, raised to the power of their respective coefficients, is equal to a contant, when other factors such as temperature are constant.

(3) PHYSICAL SIGNIFICANCE OF THE SPECIFIC REACTION RATES K_1 AND K_2, AND THE EQUILIBRIUM CONSTANT, K_c.—One of the difficult problems which the chemistry teacher encounters is getting the student to visualize the meaning of proportionality constants. The use of a set of experimental data often helps to clarify their meaning. Also the problem may be simplified if we reduce these constants to their dimensions. The dimensions of the specific reaction rates K_1 and K_2 will depend upon the order of the reaction. These questions and that of the equilibrium constants will be considered in order.

(*a*) Specific Reaction Rates.

(1) Monomolecular reaction (first order).

When experiment shows that the rate of decomposition of a substance is directly proportional to the concentration of that substance, it is called a monomolecular reaction, or if (for example)

$$A_2 \rightarrow 2A, \text{ then}$$

$$\text{Rate}_f = K_1(A_2), \text{ other factors constant}$$

The dimensions of rate are moles per liter per unit of time and the dimensions of concentration are moles per liter, therefore

$$K_1 = \frac{\text{rate}}{(A_2)} = \frac{\dfrac{\text{moles}}{\text{liters} \times \text{time}}}{\dfrac{\text{moles}}{\text{liters}}} = \frac{\text{a number}}{\text{time}}$$

The student should note that the dimensions of K_1 do not include the concentration term. This means that the value of K_1 is independent of the units in which the concentration is expressed. K_1, is, therefore, the fraction of A_2 decomposing per unit of time. Thus, if $K_1 = 0.001$ per second, then A_2 is decomposing at the rate of 0.1 per cent. per second.

Since the fraction of A_2 decomposing per unit of time is constant irrespective of its concentration it follows that the rate of its decomposition must be independent of the number of molecular collisions. This suggests that the decomposition of A_2 is a phenomenon originating within the molecule.[12]

During the course of the decomposition the concentration of A_2 varies from its initial concentration to that at equilibrium. Then the rate of the decomposition will decrease regularly to that at equilibrium. When this varying rate is treated by calculus we obtain the following expression

$$K_1 = \frac{1}{t} \log \frac{a}{a - x}, \text{ where}$$

"a" equals the initial concentration of A_2, $(a - x)$ equals its concentration after time "t." When the value of K_1 and "a" are known the concentration of A_2 at any time "t" may be calculated.

(2) Bimolecular reactions.

When two molecules of the same or different kinds react, the reaction is known as a bimolecular one, or

$$A + B \rightleftarrows C + D, \text{ then}$$

$$\text{rate}_f = K_1(A) \times (B), \text{ or}$$

$$K_1 = \frac{\text{rate}}{(A) \times (B)} = \frac{\dfrac{\text{moles}}{\text{liters} \times \text{time}}}{\left(\dfrac{\text{moles}}{\text{liters}}\right)^2} = \frac{\text{a number}}{\text{concentration} \times \text{time}}$$

K_1, in a bimolecular reaction, is *not independent* of the units in which the concentration is expressed. This constant may be interpreted as the number of moles of A or B reacting each second in each liter of the reaction mixture when the concentration of A and B are both one mole per liter (*8*).

It is sometimes pointed out in connection with the above bimolecular reaction that when (A) and (B) both equal one, then K_1 = rate. However, K_1 does not have the dimensions of rate and is numerically equal to rate in this particular case only. For example, if K_1 equals the rate when the concentrations are unity, the rate when $(A) = 3$ and $(B) = 4$ is, rate $= K_1 \times 3 \times 4 = 12K_1$, or twelve times the rate in the first case.

When A and B are present in equivalent quantities, then from calculus we learn that

$$K_1 = \frac{x}{ta(a - x)}$$

When K_1 has been determined and "a" is given, the rate of the reaction at any time may be calculated.

Since the rate of a chemical reaction taking place in bimolecular steps is controlled by the actual mechanism by which the reaction is achieved, the value of K_1 will depend on this particular mechanism. In reality it means that K_1 will depend on the slowest in the sequence of steps making up this mechanism.

One of the principal objectives of chemical kinetics is the evaluation of the velocity constant of a given reaction. From the value of this constant the order of the reaction can be determined.

(*b*) Equilibrium Constant K_c.

From the nature of the velocity constants of the forward and backward reactions in a system in chemical equilibrium and from other considerations not mentioned above, we can call the students' attention to the following summary of properties of the equilibrium constant.

(1) The equilibrium constant is the ratio of *any* pair of rate constants (K_1/K_2) selected to represent the mechanism of the reaction.

(2) It is independent of the mechanism by which the equilibrium is achieved or of the catalysts that affect the rate of the reaction. Experiment shows that, whereas different catalysts may change the mechanism of a given reaction, the same equilibrium state is reached, providing the properties of the reacting and resulting substances are not altered chemically.

[12] There is some experimental evidence that some monomolecular reactions really do involve collisions with other molecules (*8*).

(3) It is dependent on the properties of the reacting and resulting substances, the temperature and the medium in which the reaction takes place.

(4) When the ratio of the dimensions of K_1/K_2 gives a number free from the concentration term (which results when the total number of molecules on the left equals the total number of molecules on the right in the balanced equation) then the equilibrium constant is independent of the units used to express the concentration.

(5) From the value of the equilibrium constant the yield of a chemical reaction may be determined from the initial concentrations of the reacting substances. It is a measure of the completion of a reaction; of the chemical affinities involved and the free energy change.

(6) If a reaction happens to be monomolecular in one direction and bimolecular in the other, the equilibrium constant still holds because the effective concentrations occur with the same exponent in both rate and equilibrium formulas.

(7) Strictly speaking, the equilibrium constant holds only for perfect gases and ideal solutions. It does not hold for strong electrolytes. In the latter case the equilibrium constant increases regularly with increase in concentration. If activities, determined by experiment, are used instead of the analytical determined concentration terms, the constant holds for strong electrolytes. However, most of the reactions of analytical chemistry deal either with weak electrolytes or with the ions of precipitates which are present in such great dilution that calculations based on the equilibrium law are, in general, valid.

(8) Equilibrium constants may be calculated from entropy and free energy data, but thermodynamics cannot give us the values of the velocity constants.

SUMMARY

An attempt has been made to review and clarify some of the teaching difficulties encountered in presenting the Law of Chemical Equilibrium to the beginning student. While analogies may have their place in explaining some of the steps in the derivation of this law, a more convincing approach involves a more detailed and rigorous treatment. This treatment can be confined to the mathematics of college algebra, the teacher supplementing or clarifying the more difficult concepts.

Most teachers of the author's acquaintance have their own favorite methods of presenting this law. It would seem profitable if these approaches were made available to chemistry teachers in general. It is hoped, therefore, that the above treatment of the subject may be of some value to both teachers and students and that it may suggest other discussions of this subject.

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A REVISED PROCEDURE *for the* QUALITATIVE ANALYSIS *of* GROUP III CATIONS*

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INTRODUCTION

A METHOD for the quantitative separation of iron, aluminum, and chromium from the divalent ions of Group III has been proposed by Kolthoff, Stenger, and Moskovitz.[1] The method, which makes use of a benzoic acid–ammonium benzoate buffer for the precipitation of the trivalent ions as complex benzoates at a pH of 3.8, has been successfully adapted to a simple scheme of qualitative analysis for student use.

The benzoate procedure affords a number of advantages. A complete separation of the hydrous oxides from the divalent ions of the group is readily effected. Since the separation is carried out at a low pH there is no danger of the partial precipitation of

* Presented before the Division of Chemical Education at the ninety-fifth meeting of the A. C. S., Dallas, Texas, April 21, 1938.

[1] KOLTHOFF, I. M., V. STENGER, AND B. MOSKOVITZ, *J. Am. Chem. Soc.*, **56**, 812 (1934).

the hydroxide or oxy-hydroxide of manganese. In addition, the basic benzoates obtained as precipitates are very readily coagulated and may be rapidly filtered from the warm solution. The slimy and difficultly filterable precipitate obtained in the simple ammonia separation is thus avoided. The division of the Group III ions into two sub-groups minimizes the number of separations necessary and reduces the attendant errors.

A modified procedure for the separation and identification of the divalent ions of the group has been devised. The troublesome separation of the sulfides of nickel and cobalt from those of manganese and zinc by the use of cold 1 *N* hydrochloric acid is avoided. The detection of zinc is thus made easy. The separation and detection of manganese is complete and simple.

Student results with the new procedure have been compared with those obtained by the use of the conventional scheme of analysis. These results seem to justify the use of the new procedure. The procedures described below have been adapted for student unknowns of 20 ml. containing 40 mg. of each ion calculated as the metal.

PROCEDURE

1. Preparation for Precipitation.—Unless the solution to be analyzed is the filtrate from Group II, in which case dichromate, permanganate, and chromate ions have already been reduced, it is necessary to reduce these ions here. Make the solution acid to litmus with 5 *N* hydrochloric acid, and add 3 ml. in excess. Carefully add two or three drops of formalin and boil the solution until the excess formaldehyde is removed. If the solution to be analyzed is the filtrate from Group II, or if ferrous ions are present, they must be oxidized to the ferric state. Add 1 ml. of concentrated nitric acid and boil the solution for a few minutes to effect this oxidation.

2. Precipitation of Group III(A).—Add 3 *N* ammonium hydroxide to the solution from (1), drop by drop, until a very faint precipitate persists on stirring. If no precipitate forms it indicates the absence of Group III(A) ions. Add 1 ml. of glacial acetic acid and 1 g. of solid ammonium chloride, dilute to 100 ml., and then add 25 ml. of a ten per cent. solution of ammonium benzoate. Boil gently for three minutes; stir to avoid frothing. Filter the solution while hot. Aluminum gives a white, iron a tan, and chromium a gray-green precipitate. The filtrate, which may deposit crystals of benzoic acid, is retained for the analysis of Group III(B).

3. Analysis of Group III(A).—Remove the precipitate of benzoates from the filter paper and treat with 20 ml. of 2 *N* hydrochloric acid. Warm the solution until all metallic benzoates have been dissolved and only white benzoic acid remains. Cool the solution, filter off the benzoic acid, and wash the precipitate thoroughly. Discard the precipitate.

The procedure for the separation and identification of iron, aluminum, and chromium now follows the conventional scheme.[2]

4. Precipitation of Group III(B).—Make the filtrate from (2) basic with ammonium hydroxide, heat nearly to boiling, and pass in hydrogen sulfide gas for three minutes. Filter and wash the precipitate. Immediately after filtering, acidify the filtrate with acetic acid and boil down to approximately 20 ml. Cool the solution and filter off the benzoic acid. Removal of the benzoic acid at this point will aid in the coagulation of colloidal sulfides. Treat the filtrate according to the procedures for Groups IV and V.

5. Separation of Manganese.—Dissolve the sulfides from (4) by warming with 20 ml. of 6 *N* nitric acid. Pick off the sulfur with a cold spatula. Add 10 ml. of concentrated nitric acid and then 1 g. of solid potassium chlorate. Boil the solution down to 10 ml. or less. Manganese separates as hydrated manganese dioxide which is brown to black.

6. Tests for Manganese.—(*a*) The brown to black precipitate in (5) may be considered a test for manganese.

(*b*) Filter the precipitate of manganese dioxide from (5) and wash. Dissolve the precipitate in 5 ml. of 5 *N* nitric acid containing a few drops of hydrogen peroxide. Boil to destroy the excess peroxide, add an equal volume of concentrated nitric acid, and then add 0.5 g. of solid lead tetroxide. Boil the solution and allow the excess lead tetroxide to settle to the bottom. The purple color of the permanganate ion in the supernatant solution is a confirmatory test for manganese.

7. Separation of Zinc.—Make the filtrate from (5) just alkaline with 5 *N* sodium hydroxide and then add 5 ml. in excess. Heat the solution just to boiling, filter while warm, and wash the precipitate.

8. Tests for Zinc.—(*a*) Neutralize the filtrate from (7) with acetic acid and add 2 drops in excess. Divide the solution into two parts. Pass hydrogen sulfide gas into the first portion. The formation of a white precipitate is a test for zinc.

(*b*) To the second portion add about ten drops of a five per cent. solution of 8-hydroxy-quinoline in 2 *N* acetic acid. The formation of a yellow precipitate is a delicate test for zinc.

9. Solution of the Hydroxides of Nickel and Cobalt.—Dissolve the precipitate from (7) by pouring 15 ml. of warm 2 *N* hydrochloric acid through the paper several times.

10. Test for Nickel.—To 5 ml. of the solution from (9) add ammonium hydroxide until the solution is just alkaline to litmus and then 1 ml. in excess. To this solution add a one per cent. solution of dimethylglyoxime in alcohol, a few drops at a time until a scarlet precipitate has been obtained, or until a total of 5 ml. has been added. A scarlet precipitate is a test for nickel. A light brown coloration in the solution is an indication of cobalt but should not be taken as a

[2] MCALPINE, R. K. AND B. A. SOULE, "Qualitative chemical analysis," D. Van Nostrand Co. Inc., New York City, 1933, p. 324.

final test. In case a brown coloration is obtained, the quantity of dimethylglyoxime added must be greater—generally 5 ml. is sufficient.

11. Tests for Cobalt.—(*a*) "Vogel's Test." Cover 5 ml. of the solution from (9) with a 1-ml. layer of amyl alcohol. Add 5 ml. of 3 *N* ammonium thiocyanate and shake the solution thoroughly. A blue color, stable in the amyl alcohol layer, is a test for cobalt. It is known that acetone sensitizes this test for cobalt; accordingly the amyl alcohol contains approximately twenty-five per cent. acetone. If a red color develops because of the presence of ferric ions, add stannous chloride solution until this color disappears.

(*b*) Neutralize another 5 ml. of the solution from (9) with ammonium hydroxide and then make acid with acetic acid. Add about 1 ml. of a saturated solution of alpha-nitroso-beta-naphthol in fifty per cent. acetic acid and warm the solution. A brick-red precipitate is a test for cobalt.

STUDENTS' RESULTS

A record of students' results with the new procedures has been kept for a period of five semesters. During this time 384 unknowns containing the ions of Group III have been dispensed. The data given below are based on the student use of the procedures outlined above with the exception of the test for zinc with 8-hydroxyquinoline. This test, suggested to the authors by Dr. I. M. Kolthoff,[3] has only recently been introduced in the student procedures.

In order to offer some comparison with the classical scheme of analysis column five of Table 1 has been reproduced from a study of student results in qualitative analysis previously published by L. I. Gilbertson.[4]

TABLE 1

PERCENTAGE OF IONS CORRECTLY REPORTED

Metal	*Number of times given*	*Number of times reported*	*Per cent. accuracy, new procedure*	*Per cent. accuracy, classical procedure*
Cobalt	132	130	98.5	93
Iron	122	120	98.4	94
Manganese	113	111	98.2	91
Nickel	119	116	97.5	94
Chromium	70	67	95.7	89
Aluminum	148	139	93.9	84
Zinc	160	146	91.2	79
		Average	96.2	89.1

[3] Private communication.

[4] GILBERTSON, L. I., J. CHEM. EDUC., **13**, 483 (1936).

In Table 2 the data for ions reported when not present are recorded. It seemed logical to the authors to take for the percentage basis, the number of times an ion could have been incorrectly reported. Accordingly, the second column contains values of three hundred eighty-four minus *G*, that is, the number of unknowns in which the ion was not present, *G* being the number of times the ion was given as recorded in Table 1.

TABLE 2

IONS REPORTED WHEN NOT PRESENT IN SAMPLES

Metal	384 − *G*	*Number reported but not present*	*Per cent. error*
Chromium	314	1	0.3
Iron	262	3	1.1
Cobalt	252	3	1.2
Manganese	271	5	1.8
Nickel	265	5	1.9
Aluminum	236	11	4.6
Zinc	224	18	8.0
		Average	2.7

CONCLUSIONS

The data in the foregoing tables seem to indicate that, in the hands of students, the new procedures possess advantages over the classical scheme of analysis. The percentage accuracy with the new procedures is seen to exceed that obtained by conventional methods by seven per cent. In spite of the comparatively small amount of data now available it does not seem logical to the authors to suppose that this increase in accuracy is due to factors other than to the procedures themselves. The compilation of student results with the new scheme of analysis is being continued.

It is to be noted that zinc, the ion missed most frequently, is also the ion reported most frequently when not present. It is the opinion of the authors that this difficulty will be reduced by the introduction of the 8-hydroxy-quinoline test for zinc. A solution containing as much as 80 mg. each of nickel and cobalt, but no zinc, was separated in the usual way with sodium hydroxide, and the filtrate tested for zinc by the procedure outlined for the 8-hydroxy-quinoline test. Such a "blank" failed to give a test for zinc. On the other hand, it was possible to separate 3 mg. of zinc from 80 mg. each of nickel and cobalt and obtain a distinct test by this method.

CHEMISTRY *in* PUBLIC JUNIOR COLLEGES

A COMPARISON OF 1938 WITH 1928–29

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THE number of public junior colleges in the United States has increased almost one hundred per cent. during the past ten years. How does the handling of chemistry and allied fields differ now from the conditions ten years ago? How has the training and the duties of instructors in chemistry changed during this period and what are conditions now? This study is an attempt to answer these questions.

During 1929 a study was made by one of us[1] of the nature of chemistry instruction in public junior colleges. This study is an attempt to bring the material on chemistry up-to-date.

The method has been to consult the college bulletins available in The Stanford University Library and to determine from them the nature of the chemistry courses offered, and the training and duties of instructors. Table 1 presents the distribution of public junior colleges both in 1928 and 1938 and the sampling for this study. Selection was prorated among the different states so as to include both large and small colleges within each state. California, as in 1928, has the largest number of public junior colleges, and the sampling represents one-half of them. Ten of the twenty-one selected from California are of the district type and eleven of the high-school type.

TABLE 1

DISTRIBUTION OF PUBLIC JUNIOR COLLEGES IN THE UNITED STATES IN 1928 AND 1938 INCLUDING THE SAMPLING FOR THIS STUDY

State	*Number*		*Sample*
	1928	*1938*	
Alabama	0	1	1
Arizona	1	2	1
Arkansas	2	6	3
California	31	42	21
Canal Zone	0	1	1
Colorado	0	3	1
Connecticut	0	0	0
Delaware	0	0	0
District of Columbia	0	0	0
Florida	1	1	1
Georgia	2	11	4
Idaho	0	3	1
Illinois	5	8	4
Indiana	0	2	1
Iowa	20	28	9
Kansas	10	12	6
Kentucky	0	1	1
Louisiana	3	4	0
Maine	0	0	0
Maryland	0	0	0
Massachusetts	1	0	0
Michigan	6	8	4
Minnesota	7	10	5
Mississippi	4	11	5
Missouri	7	10	4
Montana	0	2	1
Nebraska	1	2	1
Nevada	0	0	0
New Hampshire	0	0	0
New Jersey	0	7	2
New Mexico	0	2	1
New York	0	0	0
North Carolina	0	1	0
North Dakota	0	6	2
Ohio	1	1	0
Oklahoma	6	21	8
Oregon	0	0	0
Pennsylvania	1	4	0
Rhode Island	0	0	0
South Carolina	0	0	0
South Dakota	0	1	1
Tennessee	0	2	1
Texas	15	22	11
Utah	0	4	2
Vermont	0	0	0
Virginia	0	0	0
Washington	2	3	1
West Virginia	0	1	1
Wisconsin	0	1	1
Wyoming	0	0	0
	126	244	106

The situation in regard to collecting enrolment data has changed since 1928. These are now given in the directory of junior colleges published annually in the *Junior College Journal*. Table 2 contains the enrolment data for the one hundred six junior colleges included in this study. The median and mean enrolments were 261 and 350 for the regularly enrolled freshmen and sophomores. In addition many of the colleges enrolled special students. There were enough of these to give each college eighty-four such students, the mean number for the colleges. The range was from no special students representative of thirty-two colleges to 3722 special students at Chaffey Junior College in California.

TABLE 2

ENROLMENT IN 106 PUBLIC JUNIOR COLLEGES, 1936–37. (FROM "THE 1938 DIRECTORY OF JUNIOR COLLEGES.")

Enrolment	*Number of colleges*	*Enrolment*	*Number of colleges*
21–50	4	301–400	17
51–75	5	401–500	8
76–100	4	501–600	4
101–125	12	601–700	4
126–150	3	701–800	1
151–175	6	801–900	2
176–200	9	901–1000	1
201–225	5	1001–2000	3
226–250	2	2001–3000	1
251–275	7	3001–5000	0
276–300	7	5001–6000	1

This table refers to regularly enrolled freshmen and sophomores. Special students averaged 84 per college with a range from 0–3722.

NATURE OF THE CHEMISTRY OFFERED

All of the one hundred six colleges studied offered chemistry. This is about the condition which existed in 1928–29 when 98.4 per cent. of the sixty-one junior colleges studied offered such courses. The median and mean semester hours of chemistry offered was 21 and 22.2 with a range of from six to sixty units as compared with a median and mean value of 16.5 and 18.2 semester units in the previous study. This is an increase in the units of chemistry offered. A distribution of semester units among the colleges is shown in Table 3.

TABLE 3

TOTAL NUMBER OF SEMESTER UNITS OF CHEMISTRY IN 106 PUBLIC JUNIOR COLLEGES OF THE UNITED STATES IN 1938 AND IN 61 IN 1928–29

Semester hours	*Number of colleges*		*Semester hours*	*Number of colleges*	
	1938	*1928–29*		*1938*	*1928–29*
0	0	1	28	4	0
6	3	1	29	4	1
8	4	5	30	3	1
10	10	10	31	0	0
11	1	1	32	2	0
12	2	3	33	3	1
13	3	1	34	3	0
14	5	2	35	1	1
15	1	3	36	2	1
16	7	7	37	0	0
17	1	1	38	3	0
18	5	1	39	0	1
19	1	0	40	0	1
20	8	3	41	1	0
21	6	0	42	1	0
22	2	3	44	0	1
23	2	0	45	1	.
24	4	4	48	1	.
25	1	4	54	1	.
26	2	2	60	1	.
27	6	1	No data	1	.
				106	61

Median 1938 21.0, 1928–29 16.5
Mean 1938 22.2, 1928–29 18.2

[1] MORSE, S. W., "Chemistry in public junior colleges," J. CHEM. EDUC., 7, 1104–12 (May, 1930).

Data were not determinable for one college. A study of the length of the chemistry course offered in the one hundred five junior colleges for which data were determinable is given in Table 4.

TABLE 4

21 or 20.0 per cent. give only one year of chemistry	(1928–29, 28.3 per cent. of 60)
19 or 18.1 per cent. give a year and a half sequence	(1928–29, 11.7 per cent.)
41 or 39.0 per cent. give two years in sequence	(1928–29, 36.7 per cent.)
24 or 22.9 per cent. give more than two years in sequence	(1928–29, 23.3 per cent.)

Perhaps the best way to compare these data with the previous study is to point out that at present 80.0 per cent. of the colleges are giving more than one year of chemistry as compared with 72.1 per cent. of the total colleges (sixty-one) studied in 1928–29.

The actual sequences and the number and percentages of colleges giving them in 1928–29 and 1938 are represented in Table 5.

TABLE 5

Sequences	*1938*		*1928–29*		
	Number	*Per cent.*	*Number*	*Per cent.*	
First-year chemistry only	3	2.9	17	27.9	
General inorganic and qualitative	18	17.1	1	1.6	
First-year chemistry and organic	18	17.1	12	19.7	
First-year chemistry and quantitative	11	10.5	10*	16.4	
First-year, organic, and quantitative	29	27.6	18*	29.5	
		75.2			95.1
First-year, organic, quantitative, and engineering materials	2	1.9			
First-year, organic, quantitative, and physical chemistry	2	1.9			
First-year, advanced inorganic, advanced qualitative, organic, and quantitative	1	0.95			
First-year, organic, quantitative, advanced quantitative, physical, and industrial	1	0.95			

* Some of them offered other courses.

It is impossible to make an exact comparison of the sequences in chemistry during 1938 and 1928–29 from the data now available. In 1938 24.8 per cent. of the colleges offered a sequence of more than first-year chemistry, organic, and quantitative analysis in order to meet their special needs. In 1928–29 fourteen or 23.3 per cent. of the sixty colleges offering chemistry gave a sequence of more than two years. Whether this means more than first-year chemistry, organic, and quantitative cannot be determined from available data. A more detailed analysis of the combination offerings of the one hundred five junior colleges in 1938 may be found in Table 6.

CHEMISTRY WITHOUT PREREQUISITES

In 1928–29 eighteen of the sixty-one colleges or 29.5 per cent. offered chemistry without prerequisites compared with thirty-seven of the one hundred five colleges or 35.2 per cent. in 1938. Of the latter there were eleven ten-unit courses, seventeen eight-unit, three six-unit, three five-unit, and one course each of twelve-, four-, and three-units. Most of these courses seemed to be self-contained courses, that is they either gave qualitative analysis in the course or were followed by a special qualitative course. The three-unit course was definitely preparatory in nature, as it consisted of five hours of lecture and no laboratory. The four- and five-unit courses were also preparatory in nature, satisfying a deficiency in high-school chemistry.

TABLE 6

CHEMISTRY COURSES AS OFFERED IN 105 PUBLIC JUNIOR COLLEGES OF THE UNITED STATES. FROM 1938 BULLETINS

Nature of the Course	*Number of Courses*	*Semester Hours*		
		Total	*Mean*	*Range*
General inorganic (no prerequisites)	37	318	8.6	3–10
General (qualitative later) with prerequisite	23	188	8.1	5–10
General and qualitative	66	603	9.1	5–10
General inorganic (qualitative not listed)	14	101⅔	7.3	5–10
General and inorganic for engineers	3	23	7.6	5–10
General for non-science majors	4	25	6.25	5–8
Elementary chemistry for pre-nursing	4	20	5.0	2–10
General for physical education and hygiene	1	5	—	—
Introductory chemistry	1	3⅓	—	—
Advanced inorganic	3	11	3.66	3–5
Inorganic preparations	1	2	—	—
Qualitative analysis (separately)	37	138⅓	3.7	2–8
Advanced qualitative analysis	4	12	3.0	2⅔–3⅓
Quantitative analysis	56	280⅓	5.0	3–10
Quantitative for engineers	1	5	—	—
Advanced quantitative analysis	3	9	3.0	2–4
Organic (including laboratory work not listed separately)	76	430⅔	5.66	3–10
Organic laboratory	15	44	2.9	2–4
Organic for agricultural students	1	4	—	—
Advanced organic	1	3⅓	—	—
Agricultural and biological chemistry	3	14	4.66	4–5
American chemistry	1	2	—	—
Applied science	2	4	2.0	1–3
Chemical principles	2	5	2.5	1–4
Engineering materials	7	20	2.8	1–6
Food analysis	2	6	3.0	3
History of chemistry	1	2	—	—
Home economics chemistry	1	8	—	—
Household chemistry	2	8	4.0	3–5
Industrial chemistry	1	3	—	—
Petroleum chemistry	1	3	—	—
Physical chemistry	3	10	3.3	3–4
Physiological chemistry	2	6	3.0	3
Power plant chemistry	1	2	—	—
Sanitary chemistry	1	3	—	—
Solutions of electrolytes	1	6	—	—
Theory and care of the skin	1	1	—	—

LABORATORY PROVISIONS

It was found that there was a large amount of variation in the number of laboratory hours allotted per unit of credit although 64.8 per cent. of the one hundred five colleges allowed three hours per unit. Some colleges, ten in number, allowed different values for different courses even having as many as three different equivalents. These facts may be summarized in Table 7.

TABLE 7

68 or 64.8% of the colleges allowed 3	hours per unit
22 or 21.0% of the colleges allowed 2	hours per unit
16 or 15.2% of the colleges allowed 4	hours per unit
3 or 2.9% of the colleges allowed 2½	hours per unit
2 or 1.9% of the colleges allowed 6	hours per unit
1 or 0.95% of the colleges allowed 5	hours per unit
1 or 0.95% of the colleges allowed 2½	hours per unit

Duplications occurred as follows:

2 and 3 hours per unit	3 colleges
2 and 4 hours per unit	1 college
2, 3, and 4 hours per unit	1 college
2½, and 3 hours per unit	1 college
2½, 3, and 5 hours per unit	1 college
3, 4, and 6 hours per unit	1 college

DUPLICATION OF FIRST-YEAR CHEMISTRY

A study was made of the duplication in first-year courses in chemistry in the one hundred five colleges (see Table 8).

ALLIED SUBJECTS

It is impossible to consider adequately the offerings in a certain field without considering the offerings in closely allied fields. In the case of chemistry the allied fields which are most important both for work in the junior college courses in chemistry and for preparation for further courses are French, German, mathematics, physics, astronomy, and geology. The last two were not included in the previous study, but it was felt that they were important allied fields and that their inclusion would give a rounded picture of the junior college offerings in physical science. The material obtained on allied fields is presented in Table 9. The corresponding table from the previous study is included for comparison. The decided changes in the offerings have taken place in German and physics, a large increase in the number of colleges offering these subjects.

TABLE 8

Duplication	*1938* Number of colleges	*1938* Per cent.	*1928–29* Number of colleges	*1928–29* Per cent.
2 courses, with and without prerequisites	26	24.8	12 of 60	20.0
2 courses, regular, and special for engineers	3	2.9	2	3.3
2 courses, regular, and special for home economics, physical education, and so forth	2	1.9	2	3.3
Total colleges offering 2 courses	31	29.6	16	26.6
3 courses, beginning, regular, and special for agriculture, home economics, and so forth	2	1.9	0	0.0
3 courses, beginning, regular and special for engineers	1	0.95	1	1.7
3 courses, beginning, regular, and special for home economics, physical education	0	0.0	1	1.7
4 courses, beginning, regular, for physical education, pre-nursing, and a cultural course	2	1.9	0	0.0
4 courses, beginning, regular, finishing for terminal courses, and for nurses	1	0.95	0	0.0
4 courses, (meeting as three), with and without prerequisites, general, for engineers	0	0.0	1	1.7
Total offering more than 1 course	37	35.3	19	31.7

TABLE 9

LOWER DIVISION OFFERINGS IN FIELDS ALLIED WITH CHEMISTRY IN ONE HUNDRED SIX PUBLIC JUNIOR COLLEGES IN THE UNITED STATES IN 1938

Subjects	*Colleges not offering* No.	Per cent.	*Colleges offering* No.	Per cent.	*Mean value of units offered*
French	8	7.5	98	92.5	19.1
German	37	34.9	69	65.1	18.4
German, Scientific	—	—	18	16.9	
Mathematics	1	0.9	105	99.1	26.1
Less than analytics	—	—	4	3.8	—
Through analytics	—	—	12	11.3	—
Through differential	—	—	8	7.5	—
Through integral or more	—	—	81	76.4	—
Physics	19	17.9	87	82.1	14.4
From 5–10 units	—	—	54	50.9	—
More than 10 in sequence	—	—	33	31.1	—
Astronomy	82	77.3	24	22.7	6.0
Geology	72	67.9	34	32.1	9.7

LOWER DIVISION OFFERINGS IN FIELDS ALLIED WITH CHEMISTRY IN SIXTY PUBLIC JUNIOR COLLEGES IN THE UNITED STATES

From 1928–29 study

French	3	5.0	57	95.0
German	33	55.0	27	45.0
Mathematics	0	0.0	60	100.0
Through analytics	—	—	10	16.7
Through differential	—	—	2	3.3
Through integral or more	—	—	48	80.0
Physics	22	36.7	38	63.3
From 6–10 units	—	—	25	41.7
More than 10 in sequence	—	—	13	21.6

THE CHEMISTRY INSTRUCTOR

Instructors in the colleges were both full-time and part-time teachers. The median and mean numbers of full-time instructors were 13 and 16.6 with a range from 0 to 183. The median and mean numbers of part-time instructors were 6 and 8.3 with a range from 0 to 31. Eight of the one hundred six colleges had no full-time instructors while fifteen had no part-time instructors.

Detailed data on the chemistry instructors could be obtained from only one hundred two colleges. It was found that 72 or 70.6 per cent. of the one hundred two colleges had only one instructor in chemistry, 17 or 16.7 per cent. had two, 5 or 4.9 per cent, had three, 4 or 3.9 per cent. had four, 1 or 1.0 per cent. had 5, 2 or 2.0 per cent. had six, and 1 or 1 per cent. of the colleges had eight instructors. The total number of chemistry instructors was one hundred sixty-two in the one hundred two colleges reported. In 1928–29 there were 1.34 instructors per college studied while in 1938 there are 1.59 instructors per college teaching chemistry.

Training of Chemistry Instructors.—The training of the chemistry instructors was determined from catalog statements. These findings are reported in Table 10. The important difference between this study and the previous one is the increase in the number of instructors with graduate work beyond the master's degree and in those holding the doctor's degree.

Instructing and Administrative Duties of Chemistry Instructors.—In so far as possible the actual teaching or administrative duties of the chemistry instructors were determined from the bulletins. Since there are many

TABLE 10

TRAINING OF CHEMISTRY INSTRUCTORS IN 102 PUBLIC JUNIOR COLLEGES, 1938

Bachelors degree only	15 or	9.3%	of 162 instructors
Bachelors degree and graduate study	7 or	4.3%	
Ph.C., B.M.E., A.C., and graduate	3 or	1.85%	
Master's degree	82 or	50.6%	
Master's degree and graduate	18 or	11.1%	
Ch.E.	3 or	1.85%	
Ph.D.	34 or	21.0%	
Total	162 or	100.0%	

TRAINING OF CHEMISTRY INSTRUCTORS IN 60 PUBLIC JUNIOR COLLEGES, 1928–29

Bachelors degree only	6 or	8.8%	of 68 instructors
Bachelors degree and graduate study	6 or	8.8%	
B.S. and B.Pd.	1 or	1.5%	
B.M.E., A.C., and graduate	1 or	1.5%	
Masters degree*	51 or	75.0%	
Ch.E.	1 or	1.5%	
Ph.D.	2 or	2.9%	
Total	68 or	100.0%	

* Includes one Ph.M. in chemistry.

junior colleges associated with high schools and employing instructors on a part-time basis in the college, this determination is sometimes difficult. The duties of the instructors are shown in Table 11.

Eighty-four or 53.8 per cent. of the one hundred fifty-six instructors for which data were obtainable taught chemistry alone. Fifty-seven or 36.5 per cent. handled two duties, thirteen or 8.3 per cent. had three duties, and two or 1.3 per cent. had four duties. The most numerous combinations were chemistry-physics, sixteen

TABLE 11

DUTIES OF CHEMISTRY INSTRUCTORS IN 102 PUBLIC JUNIOR COLLEGES, 1938

Nature of duties	*Instructors*		
	Number	*Per cent.*	
Duties not listed	6	....	
Duties listed	156	100.0	
Chemistry alone	84	53.8	
Chemistry-Physics	16	10.3	
Chemistry-Mathematics	9	5.8	
Chemistry-Geology	7	4.5	
Chemistry-Biology	3	1.9	
Chemistry-Dean	3	1.9	
Chemistry-Anatomy, Chemistry-Engineering, each	2	1.3	(2.6)
Chemistry-Dean of Men, Chemistry-Zoölogy, each	2	1.3	(2.6)
Chemistry-Registrar	2	1.3	
Chemistry-Administration, Chemistry-Assistant Dean, Chemistry-Assistant Superintendent, each	1	0.6	(1.8)
Chemistry-Astronomy, Chemistry-Athletics, Chemistry-Coach, each	1	0.6	(1.8)
Chemistry-German, Chemistry-Physical Education, Chemistry-Radio, each	1	0.6	(1.8)
Each of the following combinations had 1 instructor Chemistry-Mathematics-Athletics, Chemistry-Physics-Mechanics, Chemistry-Physics-Shop, Chemistry-Physical Education-Accounting, Chemistry-Botany-Zoölogy, Chemistry-Geology-Administration, Chemistry-Astronomy-Physics, Chemistry-Agriculture-Biology, Chemistry-Geology-Geography, Chemistry-Mathematics-Dean, Chemistry-Biology-Geology, Chemistry-Mathematics-Physics, Chemistry-Physics-Geology, Chemistry-General Science-Biology-Physics, and Chemistry-Biology-Physics-Zoölogy	15	9.6	

or 10.3 per cent. chemistry-mathematics, nine or 5.8 per cent.; and chemistry-geology, seven or 4.5 per cent. The remaining 25.6 per cent. was scattered through the rest of the combinations. The tendency has been for fewer instructors to teach chemistry alone, 53.8 per cent. instead of 64.1 per cent., but for more to teach chemistry in combination with one of the allied fields of physics, mathematics, or geology as compared with the 1928–29 study. The percentage handling more than two duties is about the same in the two studies (around ten per cent.).

SUMMARY

(1) A catalog study of chemistry in one hundred six public junior colleges of the United States has been made. Results are compared with a 1928–29 study.

(2) In so far as possible, approximately one-half of the junior colleges in each state, selected so as to include both large and small institutions from each state, have been studied.

(3) All or 100.0 per cent. of the colleges offered chemistry. The median and mean unit value offered per college was 21.0 and 22.2 as compared with 16.5 and 18.2 in 1928–29.

(4) Data on the sequence of courses, combinations of courses offered by the colleges, and hour requirements per laboratory unit have been presented. These studies were based on one hundred five colleges.

(5) A study of duplication of first-year chemistry showed that 35.2 per cent. of the one hundred five colleges gave more than one course to meet local needs as compared with 31.7 per cent. in 1928–29.

(6) In the fields allied with chemistry adequate work is being done by the junior colleges and work in German and physics has been decidedly increased since 1928–29.

(7) The average chemistry instructor in these colleges would be the holder of a master's degree with additional graduate work, the only chemistry teacher in the college, and would teach nothing except chemistry unless it was part-time high-school teaching.

LIST OF COLLEGES INCLUDED IN THE STUDY[2]

Alabama: State A. and M. Institute.

Arizona: *Phoenix Junior College.*

Arkansas: Arkansas Polytechnic College, Little Rock, State A. and M. College.

California: District type—Chaffey, *Fullerton, Marin, Modesto, Riverside,* Los Angeles, *Sacramento, San Bernardino, San Mateo, Santa Rosa.* High-School type—Antelope Valley, *Central,* Coalinga, *Pomona, Porterville, Salinas, San Benito,* San Francisco, *Santa Maria, Taft, Ventura.*

Canal Zone: Canal Zone Junior College.

Colorado: Pueblo.

Florida: *St. Petersburg.*

Georgia: Augusta, Georgia Southwestern College, Middle Georgia College, North Georgia State.

Idaho: Albion State Normal.

Illinois: *Joliet, LaSalle-Peru-Oglesby,* Morton, Thornton.

Indiana: Kokomo.

Iowa: *Burlington,* Clarinda, Estherville, Fort Dodge, Ellsworth, Muscatine, *Washington,* Waukon, *Webster City.*

Kansas: *Arkansas City, Coffeyville,* Eldorado, *Fort Scott, Garden City,* Independence.

Kentucky: Paducah.

Michigan: *Bay City,* Flint, *Grand Rapids, Port Huron.*

Minnesota: *Eveleth, Hibbing, Itasca,* Rochester, *Virginia.*

Mississippi: *Harrison-Stone-Jackson, Hinds,* Jones County, Pearl River, Sunflower.

Missouri: *Jefferson City, Kansas City, Moberly, St. Joseph.*

Montana: Northern Montana College.

Nebraska: *McCook.*

New Jersey: Morris County, Union County.

New Mexico: Eastern New Mexico.

North Dakota: North Dakota State School of Forestry, North Dakota State School of Science.

Oklahoma: Altus, Cameron State, Connors State, Murray State, *Muskogee, Northeastern,* University Preparatory, Woodward.

South Dakota: Eastern Normal.

Tennessee: Austin Peay.

Texas: Amarillo, *Brownsville, Clarendon, Edinburg,* Gainesville, Hardin, *Paris,* San Angelo, *San Antonio, Texarkana,* Victoria.

Utah: Branch Agricultural, Dixie.

Washington: *Centralia.*

West Virginia: Potomac State School.

Wisconsin: University Extension.

[2] Those schools whose names are italicized were included in the 1928–29 study.

The CHEMICAL TECHNICIAN.

PART I—

WHAT HE DOES[2]	WHAT HE USES			
OPERATIONS, DUTIES, AND SO FORTH	EQUIPMENT	MATERIALS	CALCULATIONS	DRAWING
1. Handling Dry Materials (*a*) Take samples (*b*) Store samples (*c*) Transport materials (*d*) Convey materials	Cranes Drag lines Cars Pneumatic conveyors Car dumpers Trucks Stackers Skids Bins Hoppers Sheds Barrels Packages Drums Open storage Kegs Box and gondola cars Belts Screws Elevators Conveyors Solids pumps Redlers Pneumatic flight and vibrating conveyors Continuous samplers Automatic samplers Manual samplers "Thieves" "Samplitt"	1. Character: Massive Lumpy Granular Powdery 2. Behavior: Corrosive Deliquescent Efflorescent	Depending on material to be handled or sampled See A. S. T. M. methods	Proper lettering, dating, and so forth, of samples as taken for use and storage Legibility and permanence imperative
2. Handling Fluids (*a*) Take samples (*b*) Transport material by gravity, by pressure pumping, by kinetic pumping	Thief Piping Flumes and conduits Venturi gages Fans and blowers Jets Liquid gases Valves and fittings Pumps Pulsometers Blow cases Air lifts		Volumes of tanks Capacity of pipes Use of handbook and charts Flow of water over V notch weir, 90 degrees Specific gravity of liquids	Read pipe conventions Plant piping diagrams
3. Disintegration Prepare dry materials and samples by crushing, grinding, pulverizing, shredding, chipping, and masticating	Jaw crushers Gyratories Disc crushers Hadsel mills Rolls Ball and hammer mills Ring roll mills Cage mills Chasers Hammer mills Ball and tube mills Stamps Colloid mills Ball and race mills Rod mills Attrition mills Buhrstone mills Grindstones Hogs and chippers Masticators	Rocks and ores Clay Fibrous materials Logs Straw Drugs	Time per unit per operation	Understand drawings of various types of equipment, such as assembly, cross-sections, flow sheets, process diagrams, gage charts
4. Mixing Materials By spraying, agitating, kneading, emulsifying, dispersing, and diffusing	Spray nozzles Turbine type dispensers Pumps, piping Valves Spray chambers Chasers	Solutions Fine dispersions Emulsions Pastes Powders	Time per unit per operation	Understand drawings of various types of equipment, such as assembly, cross-sections, flow sheets, process diagrams, gage charts

[1] Contribution from the Committee on Non-Collegiate Chemical Education.
[2] OLIVE *Chem. Met. Eng.*, **41**, 229 (May, 1934).

A "TRADE ANALYSIS"[1]

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Wilmington, Delaware

PHYSICAL AND MECHANICAL

WHAT HE MUST KNOW

SCIENCE	JUDGMENT	SAFETY PRECAUTIONS
Surface weathering, oxidation of dry materials, such as sulfur Chemical properties of the substance and of equipment used in handling it Proper sampling affects process control Only homogeneous materials are ready to be sampled Surface samples are unreliable	Sampling is a very responsible job which may lose money to the firm which is careless. It should stand in court if necessary Need of rapid sampling to keep moisture content as near as possible to "as received" basis Discrepancies between weights billed and weights received must be noted Angle of repose of dry materials How long sample must be kept Protecting purity of dry material; prevent waste and loss in the mass or in the sample Keep sample sealed to settle controversy	Use of masks to protect from silicosis and limey dusts, goggles Shower after work Sprinklers over piles of inflammable material Preventing skin disease from dust of certain nitro-compounds, and so forth Drum colors I. C. C. labels on drums, boxes, and cars Protection of workmen from gearing and other sources of injury Fire extinguishers First aid equipment
Pipe friction Viscosity and temperature as affecting fluid flow Acid proof cements Gaskets Corrosion of metals, pipes, and pumps Properties of materials Venturi gage principle	Need of jacketed piping for liquids which would freeze in cold weather Types of couplings of pipes Properties of steam, compressed air Types of pumps Rapid sampling of volatile liquids	Colored pipes to indicate contents Danger of opening lines under pressure or until drained Watch corrosive chemicals and *avoid excess pressure*
Solubility influenced and increased by greater surface exposed to solvent Colloidal state—grindability Intermolecular distances Quick quenching of hot materials Use of principle of "popping" corn (applied to wood fiber)	Know how fine a material needs to be for a definite use Test by sifting for per cent. completion of job Records of plant operation are important and must be kept accurately Nature of closed circuit disintegration Sound insulation	Guards on machinery—goggles, mask, and gloves for corrosive or siliceous material
Tendency of liquids to settle in layers in tanks if not mixed Effect of viscosity on mixing	Know when a mixture is homogeneous; this may require a laboratory report	Splash of corrosive or poisonous solutions to be avoided Vapors may be corrosive or poisonous

WHAT HE DOES	WHAT HE USES			
OPERATIONS, DUTIES, AND SO FORTH	EQUIPMENT	MATERIALS	CALCULATIONS	DRAWING
	Flight and screw mixers Tumbling barrels Ball mills Turbines Paddle and propeller mixers Coating pans Air-lift and air-bubble agitators Compressors Homogenizers Tanks, vats Diffusion cells			
5. Control Temperatures Control heating and cooling of reacting materials Control condensing of hot materials	Arc furnaces Resistance and induction furnaces Fuel fired furnaces Kilns Muffles Heat exchangers Condensers Cement coolers Waste heat boilers Preheaters Diesels Process coolers Refrigeration equipment Spray ponds Cooling towers Steam jet units Centrifugal vapor units Compression and absorption units Surface and jet condensers Spray chambers Fractional condensers Fractionating columns Pumps	Solid Liquid Gaseous	Specific heats Thermometry Use of handbooks Heat balances Material balances	Understand diagram of equipment Read flow sheets
6. Prepare Solutions By Leaching Dissolving Extracting Percolating Washing Gas absorption	Vats Paduca tanks Shanks tanks Woulff bottles Classifiers Ball, tube, and stamp mills Agitators Blowers Exhausters Tourills Thickeners Percolators Centrifugals Packed towers Spray chambers Bubble and plate columns Diffusion cells Condensers Separators Gas equipment Circulating pumps	Solids Liquids—miscible and immiscible Gases	Engineering units as contrasted with laboratory units of weight and measurement	Flow sheets
7. Crystallize Materials from Solution	Ponds Vats Agitators Rotary and rocking crystallizers		Time to allow maximum or optimum crystallization	Flow sheets

WHAT HE MUST KNOW		
SCIENCE	JUDGMENT	SAFETY PRECAUTIONS
Mechanical heat, electrical heat, heat from chemical energy through combustion and other reactions Direct and indirect heating Conduction, convection, and radiation heating and cooling Non-evaporative cooling, evaporative cooling, heat transfer, laws of thermodynamics, entropy Melting and freezing points Chemical and physical properties of refrigerants Air, water, spray, ice and refrigeration cooling Energy level control Heats of formation Exothermic and endothermic reactions Heat transfer surfaces Stream line flow of fluids Turbulent flow of fluids Dimensional analyses Flow at right angles to tube banks Insulation of vessels and pipes Nature of conductivity in solids, liquids, and gases Steam condensation Condensation of other vapors—mixed vapors Convection from finned or fluted surfaces Thermodynamic fundamentals Brine cooling Main refrigerants Corrosion of coils by brine and refrigerants Carnot cycle Submerged combustion Heat transfer by organic compounds and by mercury vapor Heat emission (radiation) from surfaces Temperature gradients	Protection of furnaces against overheating Conservation of waste heat; use of mercury, oil, and other substances where direct heat is dangerous Use of handbooks to secure necessary data Protection of coolers against freezing weather, proper regulation	Protection of eyes and body from heat and cold—wool clothing Precautions against electrical shock Masks for use when SO_2, Cl_2, or ammonia lines, and so forth, break
Henry's law Solutions and their properties Removal of solubles by continuous extraction, see mathematics Distribution of a solute between two solvents Effect of surface area of solute Washing one liquid with another Leaching, dissolving, extraction, percolation, washing, gas absorption	Disposal of insoluble residues Washing insolubles free from desired or undesired solubles (see Filtration) Solvent recovery problem, how handled	Guard against danger from inflammable and toxic solvents
See Solution (Block 6) Utilization of mother liquors	Treatment of mother liquors Grain size of crystals Use of non-corrosive vessels Washing mother liquor from crystals	Guard against danger of inflammables or toxic solvents

WHAT HE DOES	WHAT HE USES			
OPERATIONS, DUTIES, AND SO FORTH	EQUIPMENT	MATERIALS	CALCULATIONS	DRAWING
	Salting evaporators Vacuum crystallizers Grainers			
8. Vaporize Liquids and Solids: By Distilling Evaporating Drying Subliming	Sublimers Pumps Columns Tanks Kettles Evaporators Separators Continuous stills Pot stills Receivers	Non-corrosive metals and alloys	Time to complete a stage of this operation	Flow sheets
9. Melt Solids and Freeze Liquids	Furnaces Kettles Crucibles Reaction equipment Molds Solid CO_2 presses Refrigeration equipment	Neutral Inflammable Explosive Corrosive	Latent heat Heat of fusion Specific heat	Flow sheets
10. Control Adsorption (See Separation)	Char and contact filters False bottoms Agitated tank Packed towers	Bone char "Darco" Fuller's earth Activated carbon and alumina Sugar, oils Silica gel Other adsorbents	Rate of adsorption as influencing use of filters before revivification	Flow sheets
11. Control Electrical Separation Magnetic Electrostatic Electrophoric	Magnetic pulleys and chutes High intensity separators Huff separators Cottrell separators Clay extruder	Ores Clay "Tramp iron"	Rate of separation	Flow sheets
12. Control Filtration (See Operation 6)	Slow and rapid sand clarifiers Filter presses False bottomed tanks Thickeners Nutsches Leaf filters Edge filters Continuous filters Continuous, semi-continuous, and batch centrifuges, perforated baskets	Neutral Acid Alkaline Corrosive	Washing time of filter cake Time of building up filter cake	Flow sheets
13. Control Screening and Sieving	Vibrators Screens Sieves Microscopes and scale Grizzlies Trommels Gyrating, Shaking, Vibrating } Screens Bolters Turbines	Wire Monel metal Wood Wire and plate screens Bolting cloths	Particle size	Flow sheets
14. Control Pressing and Draining	Presses—hydraulic and mechanical Curb presses Expellers Continuous presses Tables Drawing decks Screens Classifiers Dewaterers Filters Centrifugal filters	Oils Dyes Fruit juices		Flow sheets

WHAT HE MUST KNOW		
SCIENCE	JUDGMENT	SAFETY PRECAUTIONS
Steam distillation Vacuum distillation Pressure distillation Reflux distillation Vapor pressures—partial pressures Nature of sublimation Evaporation and drying	When to change receivers When to stop evaporation When to consider material sufficiently dry When to stop subliming process	Guard against danger of inflammable or toxic solvents
Change of state Segregation of impurities in dregs of freezing liquid Aspiration principle Application of direct heat and of indirect heat (Refer to Heating and Cooling, Blocks 5 and 9)	Prevent oxidation of melted metals and other substances—use of fluxes Prevention of wastes through evaporation Prevention of gas absorption in melted metals	Avoid spattering of melted solids on pouring into wet sand or on contact with water
Bone black—use and revivification Silica gel refrigeration processes Manufacture of adsorbents Bloom or fluorescence of oils—causes and removal	When to change filter When to change adsorbent How to regulate equipment	Safety belts for use in bins of dusty or powdery, fine ground material
Principles of ionization in gases, solutions, and in fused solids Principles of electromagnetism Principles of electrostatics	Regulation of equipment	High tension electrical equipment precautions
Boyle's Law Gravity, vacuum, pressure, and centrifugal filtration principles	When operation is complete When washing of residue is complete When gages are registering correctly When to change cloths or filter screens	Protection from corrosive acid or alkaline filtrates
Passage of particle through square and round openings	Cleaning of screens and sieves	Danger of dusts in lungs (See Grinding)
Utilization of press cake of cotton seed, soy bean, linseed, and so forth Hydraulic press principles Lever and screw principle Mechanical advantage (*See* Filtration)		

WHAT HE DOES	WHAT HE USES			
OPERATIONS, DUTIES, AND SO FORTH	EQUIPMENT	MATERIALS	CALCULATIONS	DRAWING
15. Control Non-Hydraulic Settling By Flotation Classifying Chamber (settling basin) Air separation	Flotation cells Skimmers Classifiers Cones Spigot classifiers Settling basins Dust chambers Spitz kastens Cyclones Multiclones Vacuum, fan and dynamic type classifiers	Ores Graphite Clay	Pounds concentrate, percentage Pounds tailings, percentage Rates	Flow sheets
16. Control Hydraulic Settling By Jigging Tabling Vanning	Hydraulic jigs Vanners Concentrating table	Ores Clay Graphite	Pounds concentrate, percentage Pounds tailings, percentage Rates	Flow sheets
17. Control Dialyzation	Animal membranes Vegetable parchments Cellulose films as bags or diaphragms	Gelatin and salts	Calculate time of operation per unit	Flow sheets
18. Control Gas Diffusing	Porous plates	Gases	Rate—unit quantity per unit time	Flow sheets
19. Control Separation by Impinging	Washers Entrainment separators Spray chambers Air and gas filters (wetted or oiled surface) P and A tar extractor	Air Gases Solutions	Absorption rates Unit quantity per unit time	Flow sheets
20. Control Settling by Gravity (*a*) Sedimentation (*b*) Liquid settling (*c*) Centrifugal settling	Settling basins Vats Thickeners Settling tanks with multiple draw-off pipes Continuous, semi-continuous and branch centrifuges Solid basket centrifuges Cyclones	Sugar Ammonium sulfate Other crystalline materials Sewage Clays Graphite	Rates—efficiency Unit quantity per unit time Actual recovery and theoretical efficiency	Flow sheets
21. Read Measuring Instruments Interpret, inspect and adjust control devices	Samplers Thermometers Flow meters Electrical instruments Gravity and density meters Scales Poidometers Integrating flow meters Watt meters Orsats Thermal conductivity analyzers Calorimeters Control temperature Flow, feed, density and conductivity Proportioning pumps Dry and liquid feeders Weight controllers	Gases Solutions Solids	Rates and efficiency	Flow sheets to show location of such instruments
22. Observe and Inspect Catalyzers	Catalyst Chambers Converters Carriers	Metals Oxides Acids Salts	Rate of catalyst deterioration Efficiency	Flow sheets

WHAT HE MUST KNOW		
SCIENCE	JUDGMENT	SAFETY PRECAUTIONS
Colloids, sols, gels, aerosols "Froth flotation" for ore concentration Venturi meter principle	Analyses of concentrate and tailings, and interpretation	
Inertia Meaning of particle size Density	Analysis of concentrate and tailings to control process Interpretation of analysis	
Colloids Crystalloids Osmosis	When operation is complete	
Principle of diffusion of gases through various media	When equipment is functioning correctly	Precautions against poisonous gases or corrosive gases
Absorbing solutions, differential absorption	When equipment is functioning satisfactorily	Protection from caustic or corrosive sprays
Colloids Suspensoids Particle size	When equipment is functioning satisfactorily	
Principles involved in use of equipment, the physics and chemistry	When equipment is functioning satisfactorily When to test and adjust equipment which is out of order Control of valves, dampers, switches, gates, scales, manual and automatic	Removal of hot equipment from process which is not shut down
Positive and negative catalysts Relation of temperature and pressure to efficiency of catalyst	When to change or regenerate catalyst	Protection against corrosive fumes escaping from equipment

WHAT HE DOES	WHAT HE USES			
OPERATIONS, DUTIES, AND SO FORTH	EQUIPMENT	MATERIALS	CALCULATIONS	DRAWING
23. Control Flocculation, Deflocculation, and Coagulation	Settling basins Chemical feeding equipment Mechanical flocculators and deflocculators Reaction equipment, tanks, vats	Solids Suspensions	Rates Efficiency	Flow sheets
24. Control and Inspect Compression and Expansion	Compressors Molding presses Preform presses High pressure apparatus Coolers Heat exchangers Pumps Expansion valves and chambers Specialized equipment Example: masonite process Condensers	Gases Liquids Solids	Rates Efficiency	Flow sheets

PART II—

OPERATIONS, DUTIES, AND SO FORTH	TOOLS AND EQUIPMENT	MATERIALS	CALCULATIONS	DRAWING
1. Control Making of Acids For example, nitric acid	Stills Condensers Agitators Oxidation systems Absorption systems Filters Vats High pressure equipment	Salts Sulfuric acid Hydrocarbons Oxidizers Yeasts Molds Enzymes Carbohydrates	Engineering units Reading graphs and charts Yields — theoretical and actual Use of atomic weights Use of symbols and equations Weight and volume relations Use of hydrometer Use of slide rule Use of mechanical calculators	Flow sheets Use of physical and chemical symbols
2. Control Making of Bases	Evaporators Driers Filters	Quicklime Soda ash Ammonium salts Barytes Potash Salt	Yields Process efficiency	Flow sheets
3. Control Making of Salts	Evaporators Crystallizers Driers Tanks Bins Pressure carbonators	Acids Carbonates Bases Salts Alcohols	Yields	Flow sheets
4. Purify Crude or Intermediate Chemical Materials	Stills Crystallizers Absorbent trains Pumps Vats	Natural and synthetic	Per cent. yield	Flow sheets
5. Make Nitro Compounds (*a*) Nitrobenzol (*b*) Dinitrobenzol (*c*) Picric acid (*d*) Nitrotoluols (*e*) Nitrophenols (*f*) Other nitro compounds	Nitrators Thermometers Cooling coils Steam and air coils Hough type nitrators Standard type nitrator Agitators	Hydrocarbons and similar substances Nitric acid Sulfuric acid Acetic acid Anhydrides of nitric, sulfuric, and acetic acids	Theoretical and actual HNO_3 requirements —H_2SO_4 requirements Yields Preparation of acid mixtures of definite strength Use of cycle acid	Flow sheet of processes

WHAT HE MUST KNOW

SCIENCE	JUDGMENT	SAFETY PRECAUTIONS
Chemical and physical principles involved Dispersoids—particle size Water purification as good example of this operation Relation between flocculation and temperature Chemical flocculators	When equipment is functioning correctly	Cyanide antidote cans are always kept in readiness where cyanide process is in use for gold and silver
See heating and cooling, refrigeration, melting and freezing, fluid flow, distillation, fractional condensation Steels for high pressure, high temperature reaction chambers—"creep" of steels at high temperature "Cracking" process in oils—polymerization of still gases into gasoline Critical temperature Critical pressures PVT relations of gases Gas solubilities Liquid—vapor equilibria Exothermic and endothermic reactions	When equipment is functioning properly	Guard against danger of explosion from excess pressures or from vapor leaks Guard against danger from endothermic reactions induced by excess pressures or other failure of equipment to function properly

CHEMICAL PROCESSES

SCIENCE	JUDGMENT	SAFETY PRECAUTIONS
Elements, compounds, mixtures Atomic theory Reactions—reversible and irreversible Non-corrosive metals for stills Boiling points Melting points Indicators Hydrolysis Basic materials in use in the chemical industries Use of by-products Acids from salts Acids by fermentation, by direct synthesis, by oxidation of hydrocarbons or elements, oxidation of carbohydrates	Maintaining purity of product Maintaining highest economic yield Corrosion of equipment	Protection of worker from acids
Corrosion of equipment, how avoided Electrolysis of salts and bases Gas laws	Maintaining purity of product Maintaining highest economic yield Corrosion of equipment	Protection of worker from bases
Neutralization—titration Evaporation—use of mother liquors or residues Indicators	Grain size, deliquescence, efflorescence, purity of product Maintaining highest economic yield Corrosion of equipment	Protection from spattering of fused salts
Fractional distillation Fractional crystallization Cooling solutions to cause crystallization	Use of silver, Monel, platinum, or glass stills and vessels to get highest purity when desirable	Protection from poisonous dusts or other injurious conditions of material
Liquid phase nitration Vapor phase nitration Molecular reactions Nature of nitration process Basic equations of nitration Heats of formation By-products—useful or detrimental Utilization and manufacture of fuming acids—protection of special groups on aromatic rings Use of hydrometers, of electrometric equipment to determine acid strength	Denitration and recovery of weak acid "Bucking up" of weak (cycle) acids by addition of strong acids Many nitro compounds are explosive or inflammable—safety Use of hydrometers and tables in determining strength of acids Methods of moderating the violence of reaction Economic choice of nitrating agents	Use of safety showers Treatment of acid burns Use of gloves and goggles Wool clothing in acid departments Consult company and area safety rules

WHAT HE DOES	WHAT HE USES			
OPERATIONS DUTIES, AND SO FORTH	TOOLS AND EQUIPMENT	MATERIALS	CALCULATIONS	DRAWING
6. Make Amines (*a*) By reduction: 1. Aniline 2. Nitranilines 3. Other amino compounds (*b*) By Ammonolysis: 1. Anilin from chlorbenzol 2. Replacement of a hydroxyl by amino group (*c*) By catalytic hydrogenation of nitro compounds	Reducers Duriron Stoneware Agitators Autoclaves Pressure gauges Stills Condensers Receivers Pressure tanks	Nitro compounds Iron borings Sodium sulfide Hydrochloric acid Hydrogen Chloro compounds Phenols Zinc Aluminum chloride Ammonia	Calculation of metal, acid and nitro compound quantities Yields Process efficiency	Flow sheet of processes
7. Make Diazo Dyes and Compounds (*a*) Orange II (*b*) Congo Red (*c*) Benzo Blue (*d*) Other azo dyes (*e*) Diaryl compounds	Scales Tanks Agitators Ice chipper Filter press Steam coils Ice or refrigeration coils	Amines Phenols Naphthols Sodium nitrite Acids Salt or sodium sulfate	Purity of sodium nitrite Heats of formation Weights of reacting materials Yields Rate of reaction	Flow sheet and drawings of equipment to scale
8. Make Halogen Compounds (*a*) Direct: 1. Para brom anilin 2. Chlor benzol (*b*) Indirect: Meta brom nitranilin (diazotize, then reduce) (*c*) Other halogen compounds	Scales Autoclaves Distillation equipment Receivers Tanks	Chlorine Bromine Hydrocarbons See diazo reaction above	Quantities of reacting materials Yields	Drawings of equipment to scale
9. Make Sulfonations (*a*) Sulfanilic acid (*b*) Beta-napthylsulfonic acid (*c*) Other sulfonic acids	Autoclave or sulfonator Scales and tanks	Oleum Salt Material to be sulfonated Chloro sulfonic acid	Quantities of reacting materials—yields	Drawings of equipment to scale
10. Make Oxidations (*a*) Direct (*b*) Chemical	Autoclaves Pressure recorders Temperature recorders Catalysts Oxidizers Electrolytic cells	Hydrocarbons Carbohydrates Dye bases	Efficiency Yields	Flow sheets
11. Make Hydrogenations	Autoclaves Gauges Recorders Receivers Auxiliary pressure pumps and equipment	Oils Fats Bituminous coal Aldehydes Ketones Acids Alcohols	Efficiency Yields	Flow sheets
12. Make Alkyl and Aryl Compounds	Autoclaves Reflux stills Jacketed kettles	Alcohols Phenols Cellulose	Efficiency Yields	Flow sheets
13. Make Esters	Stills Reflux and downright condensers Receivers	Alcohols Acids Amides Gums	Yields Efficiency	Flow sheets

WHAT HE MUST KNOW

SCIENCE	JUDGMENT	SAFETY PRECAUTIONS
(1) Reactants (2) Mechanism and dynamics of the reaction (3) Chemical and physical factors involved (4) Design, construction, operating control (5) Applications or examples		
Theory and method of reduction, equations Acid, neutral, and alkaline reduction Consecutive reactions Catalytic reductions in vapor phase Electrolytic reduction Amination catalysts Ammonia recovery Laboratory methods of reduction *vs.* plant methods Aniline water recovery By-product utilization Economic results of new aniline process	Keep temperatures within narrow bounds to prevent formation of by-products and to prevent fire or explosions, also waste of materials	Danger of cyanosis and bladder tumors from nitro compounds and aniline Precautions Blood tests Danger of fire or explosion Need of daily shower after work Blood count Use of milk daily to combat cyanosis Cystoscope examination for bladder tumor or carcinoma Autoclaves must be observed from behind a barrier, never directly
Basic reactions and principles History of process Variations Coupling conditions Uses of products Lakes, types of azo dyes, mordants Test papers	Keep below 10° Centigrade Avoid excess nitrous acid and mineral acid Diazo compounds explosive and rarely are dried Recrystallize special high grade dyes	Compounds may irritate skin Remove them at once by washing Avoid electrical shock from wet feet, switches, and so forth
Vapor phase and liquid phase halogenation Influence of temperature Influence of catalysts Basic reactions and principles Agents Hydrochloric acid recovery Properties and uses of compounds Phenols and amines from chlor compounds Photochlorination	How to avoid formation of unprofitable by-products Check progress of reaction by distillation tests	Avoid fumes—antidotes Avoid contact with materials Disposal of hydrochloric acid by-product
Basic reaction and principles—properties and use of sulfonated materials Solubilities Sulfonating agents Separation and isolation of sulfonic acids Recovery of spent acid	Avoid formation of sulfones; avoid losses by failure to "salt out" sulfonic acid from solution properly	Avoid excess pressures in autoclaves
Micro-organic oxidizers Chemical oxidizers Valence changes during oxidation and reduction Laboratory filtration, oxidation, and reduction Partial combustion Catalysts New oxidation products in industry from petroleum Liquid and vapor phase oxidations Skraup reaction	When operation is complete or most efficient Control partial oxidation to correct stage	Danger of explosion of equipment if not controlled carefully
Chemical, electrolytic, and direct hydrogenation Useful catalysts Type reactions Economic usefulness Production of hydrogen for hydrogenation Temperature—pressure influences	When to regenerate or renew the catalyst When the yield is economically the best	Danger of explosion of equipment if not controlled carefully
Agents, products and their uses Controlling factors: concentration, temperature, solvents, catalysts Effect of alkylation	When to regenerate or renew the catalyst When the yield is economically the best	Frequent testing of equipment Precautions against alkyl lead and mercury poisoning
(Refer to salt formation and nitration blocks) Types of esters Types of reactions Agents, catalysts, mass action, law application	When operation is economically satisfactory	Frequent testing of equipment

WHAT HE DOES	WHAT HE USES			
OPERATIONS, DUTIES, AND SO FORTH	TOOLS AND EQUIPMENT	MATERIALS	CALCULATIONS	DRAWING
	Pumps Acid recovery systems	Carbohydrates		
14. Make Hydrolysis of Esters	Autoclaves Stills, and so forth High pressure equipment	Hydrocarbons Carbohydrates Esters, ethers Nitrogen compounds Proteins Sulfonic acids Fats, glycerine Starches Chloropentanes Olefins Chlorobenzol	Yields Efficiency	Flow sheets
15. Control Friedel and Crafts Reaction	Autoclaves Stills High pressure equipment	$AlCl_3$ Hydrocarbons Halogen compounds Acid anhydrides Oxides of carbon Olefins Other chlorides	Yields Efficiency	Flow sheets
16. Control Polymerization	Autoclaves, and so forth Mixing rolls Molding presses, and so forth	Phenols Formaldehyde Vinylacetylene, and so forth	Yields Efficiency	Flow sheets

RECENT BOOKS

WAVE-LENGTH TABLES. Measured and compiled under the direction of *G. R. Harrison*, by staff members of the spectroscopy laboratory of the Massachusetts Institute of Technology, assisted by the Works Progress Administration. The Technology Press, Massachusetts Institute of Technology, and John Wiley and Sons, Inc., New York City, 1939. xxviii + 429 pp. 19 × 28 cm. $15.00.

This book is probably the most valuable contribution of recent years in the field of spectrochemical analysis. The widespread use of quartz Littrow spectrographs has given the analyst sufficient dispersion for photographing rather complex spectra whose analysis has at times been difficult because of lack of adequate wave-length tables. The advantages of the new tables are more accurate listings of wave-lengths and an expanded intensity scale, which will greatly facilitate the identification of faint lines and enable the analyst better to judge of the presence of possible interfering lines.

In the M. I. T. TABLES, as this book is already universally known, there are 109,275 entries, including 1381 band heads which frequently appear on spectrograms. Intensities are given for the arc, spark, and discharge tube. The intensity scale, customarily given for a range of 1–10, has been expanded to a range of 1–9000. Twenty-five different ratings are given in this range. The new intensity scale more nearly reproduces the appearance of lines as observed on a plate, and is one of the most valuable features of the book.

The spectra of eighty-seven elements are given, for the wave-length range 10,000 to 2000 Å. The lines listed, while but a fraction of the total number of lines reported in this wave-length region, account for some ninety-nine per cent. of the radiation. With a few exceptions all lines having an intensity of 2 or more are listed. When term values are known the spectra of neutral and singly ionized atoms are designated by the numerals I and II, as in other wave-length tables. Spectra are not included for atoms in higher states of ionization. A very valuable feature of the table is the reference citation with each item.

In addition to the main table there are short tables giving (*a*) the number of lines listed for each element, (*b*) sensitive lines arranged by wave-length, and (*c*) sensitive lines arranged by elements and classified according to the order of sensitivity. These brief tables of sensitive lines are very valuable for analysis, since the presence or absence of an element can readily be determined from the relative intensities of a few lines. The reviewer, for one, would welcome the reprinting of these two tables

WHAT HE MUST KNOW

SCIENCE	JUDGMENT	SAFETY PRECAUTIONS
Vapor phase esterification Distillation of binary and ternary mixture Economic significance of esters, especially duco, rayon, acele, soaps, and so forth, also nitro glycerine, nitro cellulose, and so forth Grignard reaction Schotten-Bauman reaction		
(See bases, salts, and so forth) Alkaline fission Agents Catalysts Vapor phase hydrolyses Leather manufacture Phenol and napthols Enzymes and their uses	When operation is economically satisfactory	Frequent testing of equipment
Basic reactions, products, by-products, economic significance Constructive and disruptive effect of anhydrons aluminum chloride Chemical factors Scholl and Fries reactions Ring closures	When operation is economically satisfactory	Frequent testing of equipment
Economic value of polymers Gasoline from cracking still gases Vinylacetylenes and "Duprene" from acetylene Catalysts Basic theory and reactions By-products Recovery Synthetic resin type reactions Properties Glyptals Bakelite Vinyl resins Furfural	When operation is economically satisfactory	

on separate sheets suitable for mounting on charts for ready reference.

Much original work, as well as a tremendous task of compilation, appears in the M. I. T. TABLES. Over a quarter million lines were first cataloged, on cards; the entire spectrographic literature was covered in this list. To eliminate error a duplicate card catalog was separately made and the two catalogs were intercompared and corrected. When a line had been reported by several workers all the measurements were listed on a single card. Finally, measurements were made for some 75,000 lines in the spectrographic laboratory of the Massachusetts Institute of Technology and the results of these measurements were listed in the card catalog. Spectrographs of high dispersion were used for the experimental measurements, and an automatic comparator was developed for measuring, computing, and recording the wavelength data. Over 10,000 plates were examined. From the literature data and the experimental measurements, the best values were selected for the TABLES. Throughout the table the probable precision is indicated by the number of significant figures employed. Many of the values are given to three decimal places, and are believed to be accurate to ± 0.005 Å. Others, less accurately known, are given to one or two decimal places.

The book is well printed, with large, legible type on a durable paper. Columns are separated into sub-groups of five lines. This separation, the large type employed, and the pronounced yellow tint of the paper make the TABLES exceptionally easy to use, and tend to prevent error in reading them. The book is excellently bound, to give a long life under the hard usage which it will receive. Altogether, it seems that no effort or expense has been spared to produce the finest possible work and one which will doubtless be standard for many years. It is a book which is indispensable for every spectroscopist, regardless of whether his interests are in applied spectrochemical analysis or in the theoretical field.

W. C. PIERCE

THE UNIVERSITY OF CHICAGO
CHICAGO, ILLINOIS

ATOMS IN ACTION. *George Russell Harrison.* William Morrow and Company, New York City, 1939. xi + 371 pp. 19 illustrations. 14 × 21 cm. $3.50.

Dr. Harrison has written this book for the layman who wants a better understanding of the meaning of physics and the aim of the physicist. The result is an entertaining and informative account of the physicists' outstanding contributions to society. The reader is made acquainted with the physical principles underlying not only such familiar instruments as the telephone, camera, phonograph, radio and television set, and airplane, but also the less well known photo-electric cell, spectroscope and X-ray tube. The language is entirely non-technical and non-mathematical: the ideas are conveyed by apt simile, in terms of concepts familiar to all.

The unifying theme of the book is the control of energy as a factor in the social economy. "Energy is wealth . . . . yet this energy is free—to him who can discover how to capture and control it. The scientist who is most concerned with the investigation and control of energy is the physicist." Natural phenomena are exhibited as transformations of energy, and the discoveries and inventions of the physicist as providing the means for directing these processes to the betterment of mankind. So, in each case, the end result of the physicists' accomplishment is interpreted in terms of its contribution to human pleasure and human comfort.

Many signs indicate an ever-increasing interest on the part of the lay public in the work of the scientist, and the author has admirably achieved his purpose to offer a rational basis for this interest. Physicists will undoubtedly welcome the opportunity to place this work in the hands of their non-scientist friends.

S. L. QUIMBY

COLUMBIA UNIVERSITY
NEW YORK CITY

A HISTORY OF SCIENCE, TECHNOLOGY, AND PHILOSOPHY IN THE EIGHTEENTH CENTURY. *A. Wolf*, Professor and Senator, University of London, Head of the Department of History and Philosophy of Science, Former Fellow of St. John's College, Cambridge, Fellow of University College, London, Co-Editor of the Encyclopedia Britannica. 345 illustrations. The Macmillan Co., New York City, 1939. 814 pages. 14.5 × 24 cm. $8.00.

This interesting and handsome book, bountifully illustrated, will be a valuable addition to any school library. It is something into which a young student may profitably be encouraged to look. He will almost certainly pause of his own accord and linger; he will wish to read much of it. If he likes machines, or chemistry, or botany, or if he seeks for material for a debate on social questions, he will find here much that is pleasant to know and profitable to think about. The older student will gain perspective from it; the mature person will collect from it intellectual dividends according to the degree of his maturity.

The eighteenth century was the time of the lusty youth of that technology which now seems to have attained the fullness of its stature and vigor. It was the time, too, of keen thinking, of vast inquisitiveness, of ardent speculation, and of rigorous inquiry. One of my friends, seeing the book upon my table, remarked, "There is a book which represents real humanism." Another found it "convincing evidence that the students of political history are missing the main issue."

The book consists of thirty-two chapters which treat of mathematics, mechanics, astronomy, astronomical instruments, marine instruments, light, sound, heat, electricity and magnetism, meteorology, meteorological instruments, chemistry, geology, geography, botany, zoölogy, medicine, agriculture, textiles, building, transport, power plants and machinery, the steam engine, mining and metallurgy, industrial chemistry, the making of lenses and specula, mechanical calculators, telegraphy, psychology, the national character, demography, economics, and philosophy. The book is truly encyclopedic in its scope. The reviewer has found the last few chapters to be especially interesting, for they contain inductive and thoroughly scientific material on subjects which are sometimes mistakenly considered to be entirely speculative.

The book does not contain a satisfying history of eighteenth century chemistry. Lomonosov's part in that history is not mentioned; his name appears only in connection with a description of an anemometer which he invented. Phlogiston and Lavoisier are treated all too conventionally, in a manner which indicates a lack of familiarity both with the sources and with the findings of recent research. But the book is already large, it can't contain everything, and it does indeed tie things together in a masterly manner and exhibit their interrelationships. Its greatest interest will be for the student of the intellectual history of mankind, and this is true whether that student is, or is not, already a specialist in some branch of science or of engineering or of the humanities.

Professor Wolf's earlier volume on the Sixteenth and Seventeenth Centuries is reviewed in THIS JOURNAL, **13**, 147–8 (March, 1936).

TENNEY L. DAVIS

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CAMBRIDGE, MASSACHUSETTS

COLLOIDAL PHENOMENA. *E. A. Hauser*. McGraw-Hill Book Company, Inc., New York City, 1939. xx + 294 pp. 14 × 20 cm. $3.00.

In the author's own words, it is not his intention to offer another textbook on colloidal chemistry since a sufficient number already exist. He hopes "to acquaint the reader, in as simple a manner as possible, with the modern viewpoints in colloidal science and to show where and why they must differ from those so successfully applied in physico-chemistry. It is further hoped that such discussions may be helpful in eliminating the belief, still prevalent in some circles, that the science of colloids must be considered either as a development entirely independent of any other branch of known science, or that colloidal phenomena must be fully explained in accordance with laws of classical chemistry or physics. . . . These courses (at the Massachusetts Institute of Technology) have proved that the average student comprehends a logical presentation of such a subject more readily than a mathematical treatment."

Dr. Hauser has realized his hopes very successfully in this helpful book. He writes very clearly and expresses himself very positively. The colloid chemist may not always agree with his viewpoint, but he will understand exactly what the author is saying.

The reviewer liked particularly the very definite discussion of charge and hydration influences, the unusually good discussion of the theories of swelling, the treatment of the coacervation theories of Kruyt and Bungenberg de Jong, the section on the optics of colloids, and the treatment of colloidal aggregates.

Adsorption is not dealt with at great length, although it is of major importance. On the other hand, the principles and theories of adsorption are very well taught. "Quite frequently we find that physical adsorption is predominant at low temperatures, such as in the adsorption of oxygen on metal surfaces; whereas at elevated temperatures an activated adsorption on chemical localization takes place. This difference finds its simple explanation in the fact that chemical reactions proceed extremely slowly at low temperatures."

The reviewer is somewhat dismayed by the extreme brevity of treatment of emulsions and by the limited discussion of gels. Silica gels are touched upon very lightly, with no mention of Patrick's important work in this field. The author seems to be rather more familiar with European work in the colloid field than with the very important American research.

The appendix is extremely useful, offering, as it does, many important formulas and technics. It contains also an excellent discussion of infra-red spectroscopy, fluorescent light microscopy, and the theory of X-ray diffraction.

Dr. Hauser's book is clearly a useful addition to the colloidal library. It will justify future editions as the rapid advance of the subject makes such revisions necessary.

HARRY N HOLMES

OBERLIN COLLEGE
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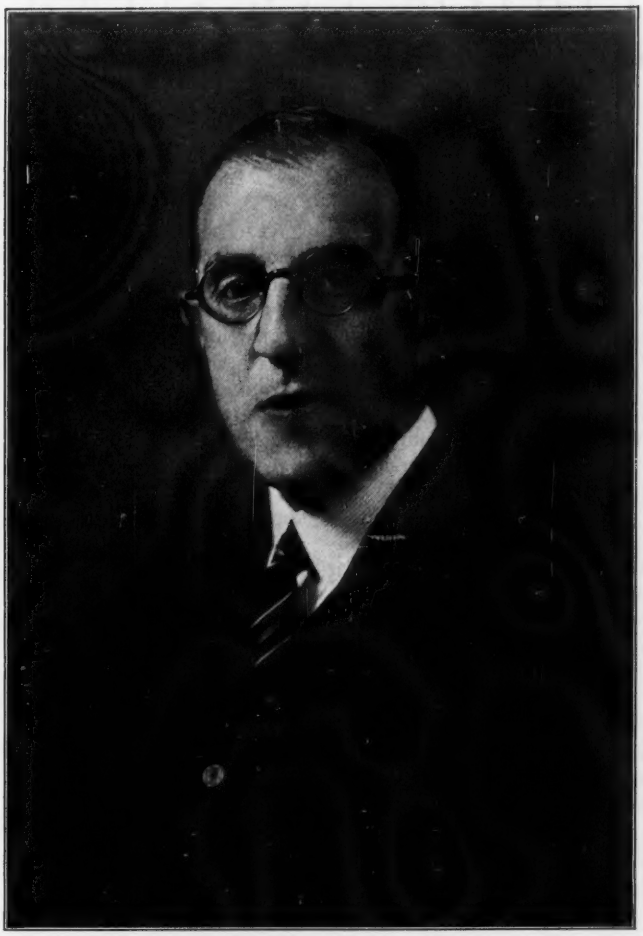
EDUCATIONAL ACTIVITIES OF THE WORKS PROGRESS ADMINISTRATION. *D. S. Campbell, F. H. Bair* and *O. L. Harvey*. U. S. Government Printing Office, Washington, D. C., 1939. xiv + 185 pp. 15 × 23.5 cm. $.25.

THE ENGINEERS' MANUAL. *R. G. Hudson*. John Wiley and Sons, Inc., New York City, 1939. Second Edition. iv + 340 pp. 12.5 × 20 cm. $2.75.



ISADOR M. HEILBRON (1881–)

In June, 1939, the University of Glasgow conferred an honorary LL. D.on one of its alumni (D.Sc., 1919) for his distinguished achievements in organic chemistry. I. M. Heilbron, born at Glasgow, November 6, 1886, was trained at the Royal Technical College in that city and then at Leipzig, where he obtained his Ph.D. in 1910 under Hantzsch. In 1909, he was appointed Lecturer at the Royal Technical College, and held this post until 1914 when his academic career was interrupted by the Great War. He became Lieutenant in the Royal Army Service Corps, and saw service in Egypt and Salonika. He was mentioned in the despatches three times and was the recipient of the Distinguished Service Order, Greek Order of the Redeemer, French Medaille d'Honneur. By the close of the War, he was Lieutenant Colonel, Assistant Director of Supplies.

He returned in 1919 to the Royal Technical College as Professor of Organic Chemistry, was called to the chair of chemistry at Liverpool University in 1920, where he remained until 1933 when he was appointed to a professorship at the University of Manchester. In 1938 he was called to his present position in the University of London (Imperial College) where he is Professor of Organic Chemistry and Director of the Laboratories.

Dr. Heilbron was made a Fellow of the Institute of Chemistry (F.I.C.) in 1911, and Fellow of the Royal Society (F.R.S.) in 1931. He was awarded the Longstaff Medal of the Chemical Society of London in 1939.

His publications began in 1909 with some joint papers with G. G. Henderson on terpenes; he soon began to issue independent studies. These now number about two hundred, dealing principally with sterols, vitamin A, vitamin D, squalene, triterpenes, algal pigments, pyrylium salts, spiropyrans, and so forth. His monograph "Sterols" appeared as part of *Fortschritte der Chemie organischer Naturstoffe;* his "Vitamin A" in *Ergebnisse der Vitamin und Hormon Forschung.* He is Editor-in-Chief of the well-known and valued three-volume "Dictionary of Organic Compounds."

(*Contributed by Ralph E. Oesper, University of Cincinnati*)

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EDITOR'S OUTLOOK

IS CHEMISTRY MORE COMPLICATED? Several times, speaking on announced subjects that we do not now recall, but which are doubtless well known to collectors of Ford Motor Company reprints, our radio friend, Mr. Cameron, has developed the idea that, despite the pronouncements of some social observers and investigators, and the dicta of many supposedly thoughtful general commentators, life today is actually less complicated than it was for our great-grandfathers. In a paraphrased and extremely condensed version of Mr. Cameron's thesis one need not now be his own carpenter, mason, smith, plumber, surveyor, architect, engineer, agronomist, horticulturist, apiarist, husbandman, veterinarian, butcher, packer, etc., etc. On the whole, the average man now has, both in the sustaining and enriching activities of life, more (and more competent) partners than our great-grandfathers could command.

Purely on our own responsibility, we adopt Mr. Cameron's thesis and apply it specifically to the life of the modern teacher of chemistry.

Chemistry has become more and more extensive, and more and more departmentalized. Many persons assume, therefore, that it has become more and more complicated. It does not seem to us that this is either a logical conclusion or the reflection of a healthy mental attitude. It is true, of course, that the total body of chemical information, rumor, and speculation can no longer be condensed into a one- or two-volume treatise of practical textbook dimensions. It is true also that no one man can any longer hope to examine and evaluate in detail the current production of chemical literature. But these facts need not give rise to the sense of futility and frustration that afflicts many a conscientious lecturer and textbook writer with neurotic headaches.

It would be either stupidly smug or blindly pessimistic to maintain that all the great chemical discoveries have been made, and that the future offers the undramatic prospect of mere elaboration of detail or unimaginative extension of area. On the other hand, it may be conceded with simple justice that our scientific forebears have, on the whole, built soundly and well. It is wildly improbable that we shall awake on some catastrophic morning to find that the foundations or the elementary structural members of the science have been shattered overnight by the meteoric impact of a hitherto unforeseen discovery.

Actually the tasks of the genuine scientist, the competent author, and the scholarly teacher have been simplified rather than complicated by the "era of abundance" into which we have now entered. One need no longer be his own librarian, abstractor, compiler, indexer, dishwasher, analyst, etc., etc.

Time was when the industrious compiler could pass for a lecturer or author. If, in addition to industry, he had a rudimentary talent for the logical organization and presentation of subject matter, he masqueraded as a profound scholar and a genuine scientist. He was able to lug in the entire carcass, and he did; so no one could accuse him of having left any important member of it outside. The mutilated cadaver didn't always look lifelike, and it was sometimes assembled in fantastic ways, but no one could complain too vigorously, for it was undoubtedly all there. Carcasses are now too big to be delivered entire in the elementary classroom. However, the genuine scholar, supported by a sound knowledge of anatomy, still finds the skeleton and the vital organs a fairly compact and manageable load for an able man. The congenital compiler, on the other hand, finds the task of dissection and selection too "complicated." He cuts off what he judges to be the head as far down the neck as possible; then to show that he is up-to-date he lops off the tail and any other more or less spectacular appendages that engage his fancy; laden with these trophies he returns to the classroom and announces that he has signed over his rights in the residue to the graduate-school specialists.

The solution has relieved the pressure only in part, and only momentarily. For the pseudo-scholar life is indeed complicated, and makes every threat of becoming more so. Eventually, however, some of the problems of others will be simplified by the elimination of his competition.

HISTORICAL OBSERVATIONS DURING *a* RECENT CHEMICAL TRIP *to* EUROPE[1]

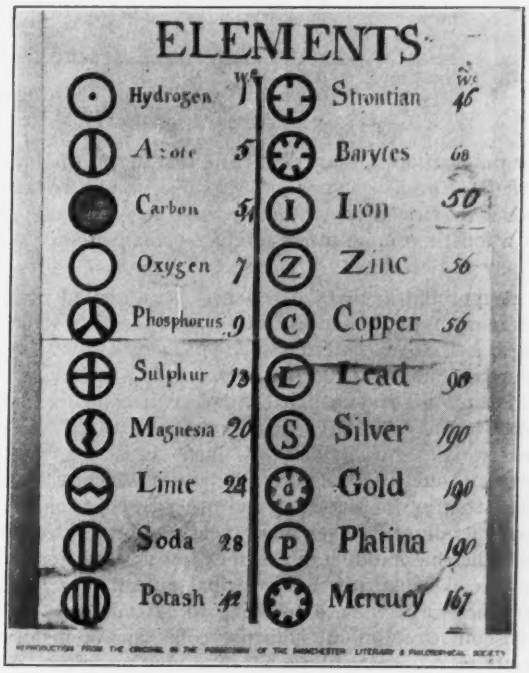
C. A. BROWNE

Bureau of Agricultural Chemistry and Engineering, United States Department of Agriculture, Washington, D. C.

INCIDENTAL to an agricultural chemical survey of research work in several European countries in the summer of 1938, the writer devoted a little time to historical chemical pursuits. These comprised visits to scientific museums and libraries in several of the principal cities of England, Scotland, France, Holland, Sweden, and Denmark and conversations with foreign chemists who are interested in the history of chemistry.

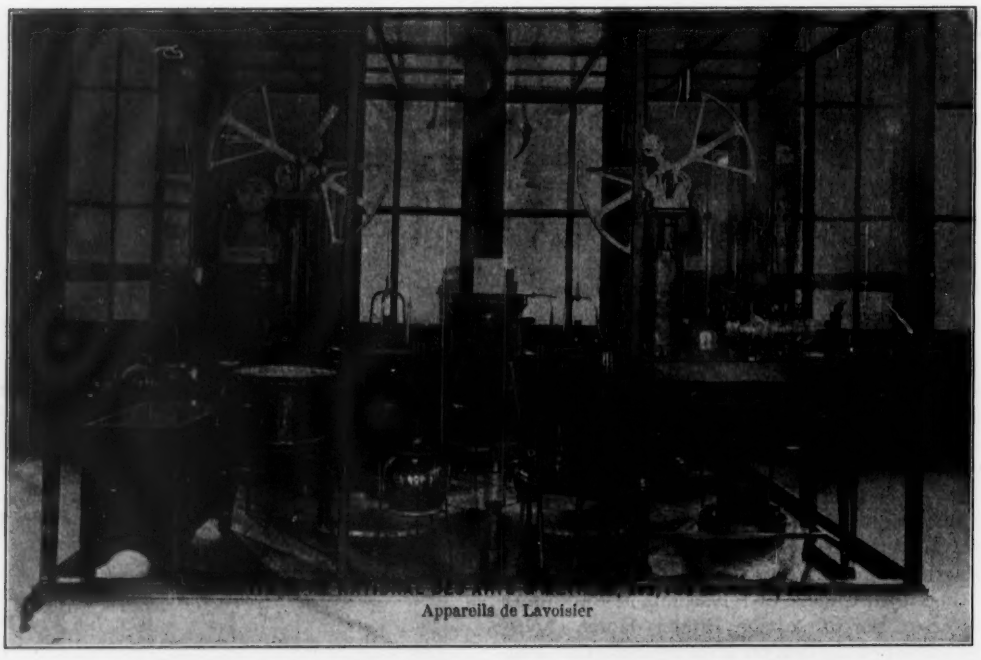
As an agricultural chemist, the writer visited the library of the Royal College of Physicians in Edinburgh where he saw a portrait of Dr. Francis Home (1719–1813), the author of the first book on agricultural chemistry which was published in 1757 under the title "Principles of Agriculture and Vegetation." Second and third editions were published in 1759 and 1762; a French translation was issued in 1761 and a German translation appeared in 1779. Almost contemporaneous with Home's English work was the book on agricultural chemistry by Wallerius, entitled "Agriculturae fundamenta chemica," published in both Swedish and Latin at Uppsala in 1761. It was a thesis by Count Gyllenborg, one of Wallerius' students, but the work was inspired by and is rightfully credited to Wallerius. While he was at Uppsala the writer looked up the list of the dissertations that were conducted under Wallerius, and there were ninety-seven of them between the years 1740 and 1766, all of them preserved in the University Library. Many of these dissertations are of an agricultural chemical nature, such as the one by J. G. Bergman in 1754, entitled "Causae Sterilitatis Agrorum." The Wallerius-Gyllenborg treatise on agricultural chemistry like that of Home, is a work of great rarity.

Of the interesting museums that were visited, mention should be made of the very complete collections of apparatus and memorabilia of Dalton in the building of the Manchester Literary and Philosophical Society; the Old Ashmolean Museum at Oxford where the writer saw a very elaborate new Accum item consisting of a beautiful cabinet of coal gas by-products prepared by this chemist; the historical chemical collections in the Science Museum and in the Royal Institution of London; the priceless collection of Lavoisier apparatus in the Conservatory of Arts and Crafts at Paris; the very complete collection of historical exhibits relating to the chemistry of fermentation in the museum of the Carlsberg Brewery in Copenhagen; and the very extensive collection of apparatus, specimens, laboratory preparations, manuscripts, letters, photographs, decorations, books, and other memorabilia of Berzelius in the Swedish Academy of Sciences at Frescati near Stockholm. The important collection of Berzelius relics by Gustav Lindstrom forms the nucleus of this museum. Berzelius was secretary of the Swedish Academy from 1818 to 1848 and, being a most copious letter writer, his correspondence fills many cases. In response to an appeal by Mr. Holmberg, the librarian of the Academy, many new Berzelius letters have been brought to light, and these are now being assembled



DALTON'S TABLE OF ELEMENTS (1806–7). REPRODUCED FROM THE ORIGINAL IN THE POSSESSION OF THE MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY BY THE SCIENCE MUSEUM OF LONDON

[1] Presented before the Division of the History of Chemistry, at the ninety-seventh meeting of the A. C. S., Baltimore, Md., April 5, 1939.



APPARATUS OF LAVOISIER, CONSERVATOIRE NATIONAL DES ARTS ET METIERS, PARIS

for publication. Many new facts relating to the life of Sweden's great chemist are disclosed and this additional material will necessitate very soon the addition of a fourth volume to Söderbaum's compendious biography of Berzelius.

A museum in Sweden which is little visited by the ordinary tourist, because of its comparative remoteness, is that of the famous Kopparberg Mining Company at Falun. This company, which is probably the oldest mining and chemical company in existence, dates back to the year 1284, and it is probable that the mine was worked long before this time. It is very rich in ores and minerals, the examination of which attracted the attention of Berzelius and other Swedish chemists and metallurgists over many years. Formerly copper was the chief product of the mine but now pyrites, zinc, and lead constitute the principal output, the annual production of these amounting to 110,000 tons. The museum contains an immense collection of historical material consisting of models of mining machinery used at different periods of Falun's history; exhibits of ores and minerals; chemical products made by the Kopparberg Company; metal castings made from ores of the mine; dioramas of smelting operations; and other exhibits too numerous to mention.

The museum building of the Kopparberg Company is on the brink of an enormous cavity, called the "Big Pit," produced by a downfall of the mine in 1687. On the walls of the pit can be seen the openings of long disused galleries which were left exposed at the time of the mine's collapse. On the edge of the pit, fronting the museum, is a mine head over the entrance of which are painted the alchemical signs for gold, silver, copper, iron, mercury, antimony, tin, sulfur, vitriol, and so forth. Although of modern construction, this decoration is a fitting symbol of the antiquity of the mine which dates back into the dim centuries of early alchemy, when metals were supposed to be engendered in the earth by planetary emanations.

It is interesting to know that Emanuel Swedenborg,[2] the famous Swedish philosopher, mystic, and scientist, in his early capacity of metallurgist and chemist, published in 1734 a Latin treatise, entitled "Regnum Subterraneum sive Minerale de Cupro et Orichalco," in which he discusses the methods of mining and smelting copper ores. The book is one of the most important works on the early metallurgy of copper that we have and in it Swedenborg devotes several chapters to a description of the operations at Falun. Last year, which was the two hundred fiftieth anniversary of Swedenborg's birth, the British Non-Ferrous Metals Research Association published in collaboration with the Swedenborg Society an English translation by Arthur Hodson

[2] Emanuel Swedenborg (1688–1772), the celebrated philosopher and mystic, author of some forty theological works and founder of the New Church, was also a distinguished scientist and metallurgist. For thirty-one years from 1716 until 1747 he was assessor-extraordinary on the Swedish board of mines. He visited Swedish, Saxon, Bohemian, Austrian, and other European mines and wrote numerous reports on smelting and assaying. His metallurgical works were published in 1734 in Latin, one volume of these deals with iron and steel and another with copper and brass. Swedenborg's theories of atoms, light, magnetism, and so forth, anticipated many later discoveries. He was the first to employ mercury for the air pump and also the first to give a lucid account of phosphorescence. According to Dumas, the French chemist, Swedenborg made the first serious attempt to establish a system of crystallography.

Searle of Swedenborg's "Treatise on Copper," from which the following passages are quoted. The first passage is from the preface in which Swedenborg in gorgeous allegory thus described the mine at Falun:

"How great an abundance of copper has not been afforded to its miners by that great mine at Fahlun which is still unexhausted after having been continuously worked for a period of a thousand years down to the present day!; insomuch that for several years, when, about 1659, the great lode was discovered, it yielded 60,000 cwt. of copper yearly; so that all its foundations, doors, grottoes, walls, porticoes, halls, and columns were thrown open to their fullest extent, the ore glittering on all sides with a ruddy glow and almost blinding the eyes with rays of golden colour, so that the guests now coming from Fahlun, seemed to be as it were introduced into the presence of Venus herself sitting as a bride or newly wedded wife in her most splendidly decorated bridal chamber, ready to receive and welcome them most joyfully. Not to mention the abundance of masses of native copper hidden away here and there, and brought to light."

Photograph copyright by the Stora Kopparberg

EXHIBIT OF MODELS, TOOLS, PHOTOGRAPHS AND CHARTS OF CHARCOAL BURNING IN THE INDUSTRIAL MUSEUM OF THE STORA KOPPARBERGS BERGSLAGS AKTIEBOLAG, FALUN, SWEDEN

At the beginning of Chapter I Swedenborg gives us a vivid picture of the age of the Falun mine and of its appearance over two centuries ago:

"The Fahlun mine, which is called the great Copper Mountain and Mine, is deservedly reckoned among the most ancient monuments of the North and of the Kingdom of Sweden. It still deserves to be raised to threefold honours, because it is to this day inexhausted and ceases not to offer, every year, to its miners and to the public, its copper treasures so deeply and extensively stored away and preserved. In vain do we inquire into its origin and birth, since it exceeds in age several centuries and perhaps a thousand years. We may in some measure judge of its old (great) age from certain signs, for instance, from the clefts, caverns, trenches and, as it were, the wrinkles, which it had produced so very conspicuously; for so much of the earth and mountain has been excavated that it seems as if many centuries would barely suffice to produce such an effect. An abyss and immense crater yawns open in the middle; at its sides, in different directions, there are hundreds of pits and excavations leading on and on to gullets[3] and new abysses, and in every direction from one excavation to another the mountain is seen to be honeycombed; and from these excavations towards the deeper parts, where in like manner other caves and hollows succeed, and, from these again, there open out descents into fresh grottoes and mines, and thus they make a great highway, exceeded in breadth by none other anywhere on earth, to the infernal regions of ancient writers, and the realm of Pluto. At the present day, indeed, through the wear of so great a length of time, and by the removal of so many mountain-loads, it has already become weakened with age, and gapes open with fissures here and there; and very frequently quakes and totters, and indeed often buries up the underlying excavations by frequent landslips."

This description of the "Big Pit" tallies very closely with what one may observe today.

At the National Norse Museum in Stockholm the writer visited a part of Scheele's original apothecary shop and in Uppsala paid a visit to the drug store on

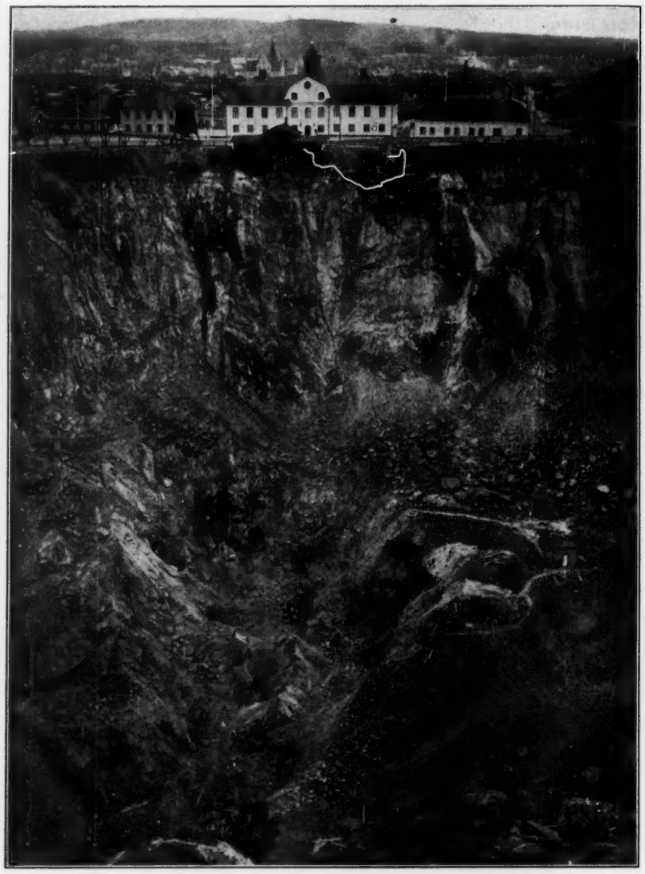
[3] Gullet is an engineering term and means an artificial excavation. Gullies are made naturally by rain or torrents.

which a tablet states that Scheele lived and worked there between 1770 and 1775. During the summer's trip a number of restorations of old drug shops were visited—several very interesting ones in the Wellcome Museum for the History of Medicine in London, several at the Norse Museum in Stockholm and a very interesting old apothecary shop with laboratory at the Municipal Museum in Amsterdam. So many of the early great chemists obtained their first training in drug stores that the history of early pharmacy and chemistry cannot be dissociated.

Very enjoyable features of the trip were the opportunities of examining the large private collections of portraits, prints, autograph letters, and so forth, of Mr. Richard Pilcher, Registrar and Secretary of the Institute of Chemistry in London and of Professor Ernst Cohen at the University of Utrecht in Holland. Last year was the two hundredth anniversary of the death of Boerhaave, and Professor Cohen spoke of the discovery of many new Boerhaave letters and manuscripts in Russia, which promise to throw much new light upon the career of this famous Dutch chemist. There are few writers who contribute so many monographs upon all phases of the history of chemistry as Professor Cohen. His contributions appear not only in Dutch, but in English, French, and German.

In London the writer had a very pleasant visit with Dr. F. Sherwood Taylor, editor of the new historical chemical quarterly "Ambix." The late Sir Robert Mond was very helpful in giving "Ambix" the necessary financial assistance at the beginning, but the future of "Ambix" is now in jeopardy because of Sir Robert's recent death and the uncertainty of other support. The annual deficit of "Ambix," according to a statement issued last January, is about one hundred fifty pounds. It is hoped that the recent appeal of "The Society for the Study of Alchemy and Early Chemistry" may be successful in increasing the number of subscribers to "Ambix" so that this very deserving journal may become self-supporting.[4]

In visits to the Library of the Royal Society, considerable attention was devoted to examining manuscripts and letters that pertained to the history of chemistry in the English Colonies of North America during the seventeenth and eighteenth centuries. The writer discussed, many years ago before the Division of the History of Chemistry, the chemical work of John Winthrop, Jr., of New England, whom he called America's first chemist, although he was criticized for this somewhat facetiously in the *Literary Digest* at the time of the Winthrop Tercentenary in 1935. The criteria upon which Winthrop's claims are founded were all based on verifiable documents and consisted of the following: He was the first American to equip a chemical laboratory; he was the first to assemble a chemical library; he was the first to collect a museum of chemical curiosities; he was the first to belong to a scientific society; he was the first to present a chemical paper before a scientific society; he was the first to take up in a serious scientific manner the chemical exploitation of America's natural resources; and he was the first to leave behind an extensive correspondence on chemical subjects with European scientists. When the Editor of *Literary Digest* was requested to mention an earlier American chemist to whom these criteria could be applied, he was unable to do so.



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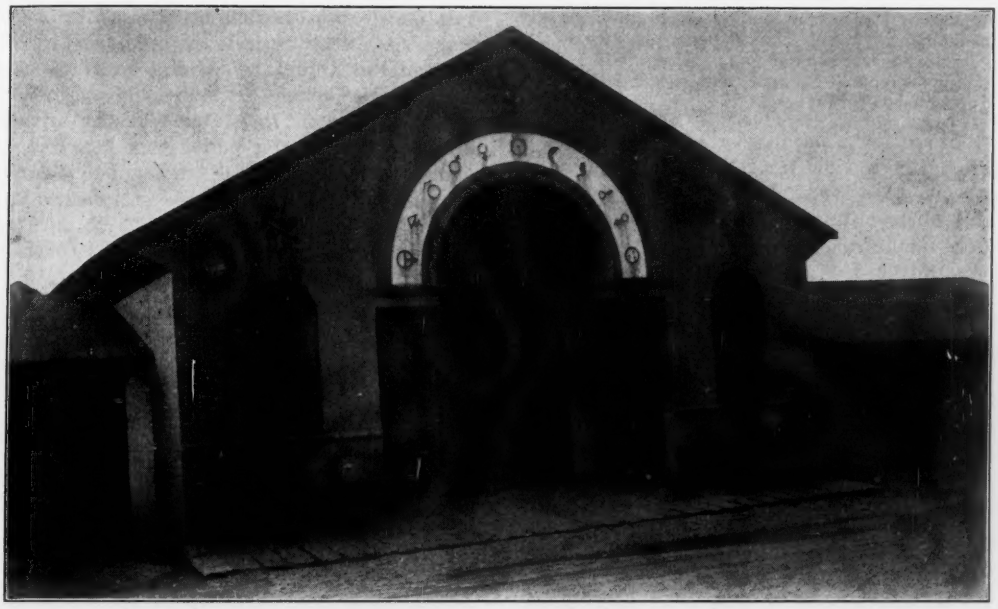
THE FALUN MINE: THE "BIG PIT" WITH THE OLD MAIN ENTRANCE AND THE INDUSTRIAL MUSEUM OF THE STORA KOPPARBERGS MINING COMPANY. CITY OF FALUN IN BACKGROUND

Many of Winthrop's letters can still be seen in the files of the Royal Society. But it is not to Winthrop that the concluding part of this paper is devoted but to another chemist of English birth who, if he had re-

[4] Since the above paragraph was written the regretful news has arrived that circumstances have made it necessary to discontinue the publication of "Ambix."



Photograph by Mrs. C. A. Browne

THE OLD MAIN ENTRANCE OF THE KOPPARBERGS MINE, FALUN, SWEDEN, WITH ALCHEMICAL SYMBOLS

mained in the Colonies, would have earned the distinction of being America's first Agricultural Chemist. This was the Reverend Dr. John Clayton, who came to Jamestown, Virginia, in 1684 and after a two years' residence there returned to England in 1686. Like Winthrop, he was a member of the Royal Society and a friend and correspondent of Boyle. Except for a few occasional personal references contained in his writings very little is known, however, about Clayton himself. He has been confused with John Clayton (1686–1773) the Virginia botanist, of a later generation, no less a publication than the British National Dictionary of Biography having grossly erred in this respect.

Clayton's references to his anatomical studies in London with Dr. Allen Moulin and the frequent mention in his writings of the treatments which he gave people for different ailments indicate that he must have prepared for the practice of medicine. During this London period Moulin and Clayton gave demonstrations of their experimental work on animals before the Royal Society, and these occasions brought Clayton into close contact with Boyle, Hooke, Grew, and other leading English scientists of the day. It is to the influence of these contacts that we may attribute in large measure the immense range of Clayton's scientific interests. He was not only well versed in medicine and anatomy but he was a skilled chemist and his various reports are filled with allusions to agriculture, meteorology, zoölogy, botany, and other sciences.

The motives which influenced Clayton to turn from medicine to divinity are unknown. This change, however, involved no relinquishment of his scientific interests which, as in the case of Stephen Hales, Joseph Priestley, Richard Watson, and other eminent English divines, continued to occupy a considerable part of his time and attention.

Clayton's visit to Virginia in 1684 was undoubtedly planned for the purpose of conducting a scientific survey of the natural resources of the colony. As stated in the beginning of his first letter to the Royal Society of May 12, 1688, he had provided himself with books, chemical instruments, microscopes and other scientific apparatus but the loss of all this equipment in the wreck of the ship that followed him prevented him from carrying out the full purpose of his original design. But notwithstanding this privation, Clayton's reports upon the soils, minerals, springs, wild life, agriculture, and other natural resources of Virginia contain much of scientific value and interest. His remarks on the soils of Virginia and their relation to the quality of the crops grown thereon, on manures, and other agricultural subjects are still pertinent. They are the earliest American references to soil science, and when we consider what Clayton might have accomplished in this field under more favorable conditions, the loss of his apparatus and the shortness of his stay in Virginia can be viewed only as a great misfortune.

After a "tedious long voyage" of twelve weeks from England on the ship *Judith*, Clayton wrote a hasty letter to his friend Dr. Edmund Borlase, dated James City, April 24, 1684,[5] in which he remarks:

[5] Published in the *William and Mary Quarterly*, 2nd Series, Vol. I, pp. 114–5. The writer in his recent examination of this letter in the British Museum could not find the name of the addressee upon it, but it is indexed in the Museum Catalog as having been written to Dr. Edmund Borlase.

"Tis now our Great Assembly and on Sunday by a peculiar order from the Governor and Councill I am to preach so that something peculiar is expected and I must mind my hits to preserve that blooming repute I have got. I have had the happiness to be cried up far beyond my deserts."

This reference to "a peculiar order" would seem to indicate that Clayton did not visit Virginia primarily in the capacity of a preacher. He lived on a tobacco plantation[6] where he made practical experiments and observations upon drainage, manuring, and cultivation to the great disgust of the overseer who remarked

Photograph obtained from the Uppsala domkyrka

SARCOPHAGUS OF EMANUEL SWEDENBORG—METALLURGIST, SCIENTIST, AND PHILOSOPHER (1688–1772)—IN THE CATHEDRAL OF UPPSALA, SWEDEN, WITH TRIBUTES IN COMMEMORATION OF THE TWO HUNDRED FIFTIETH ANNIVERSARY OF HIS BIRTH

scornfully that he "understood better how to make a Sermon than managing Tobacco." The lady who owned the plantation thought differently, however, and discharging her overseer gave Clayton the opportunity of putting his ideas into practice, which he did apparently with good results. It is to this circumstance, no doubt, that we owe the vast amount of attention which Clayton gave to agriculture in his subsequent reports to the Royal Society.

Clayton, in conformity with the style of Boyle, Grew, and other authors of his day, was a most diffusive writer, and his scientific remarks are interspersed with random observations that are often far remote from the subject under discussion. Yet it is largely due to this discursive habit that we are able to form an idea of the activities and personality of the author. Like some other English writers of a later day, Clayton was extremely critical of the customs and methods of Colonists.

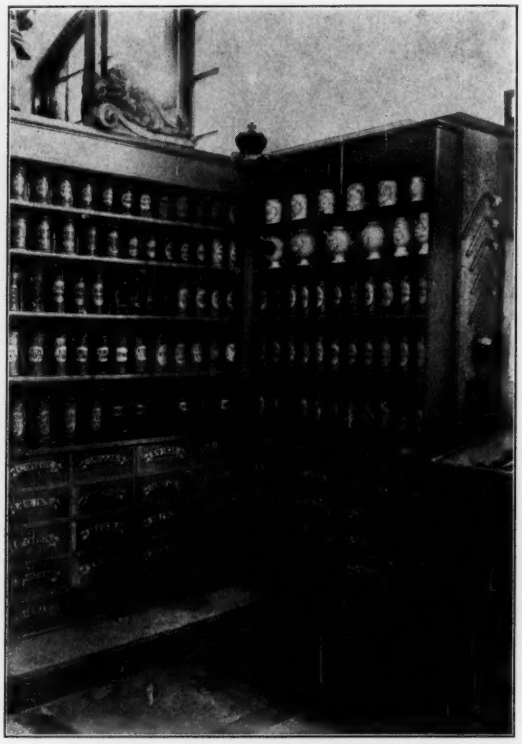
"Tis strange," he remarks, "in how many things they are remiss, which one would think *English* Men should not be guilty of."[7]

And again, "they are . . . conceitedly bent to follow their old Practice and Custom, rather than to receive Directions from others, tho' plain, easie and advantageous."[8]

[6] *Phil. Trans. Roy. Soc.*, **17**, 980–1 (1693).
[7] *Ibid.*, **17**, 985 (1693).
[8] *Ibid.*, **17**, 982 (1693).

Clayton's insatiable curiosity was tinctured with a somewhat assertive pride of opinion, that was not exactly relished by some of his Colonial associates.

After his return to England in May, 1686, Clayton became Rector of Crofton, at Wakefield in Yorkshire, and it was during this period that he wrote his "Account of several Observables in Virginia" that appeared in a series of letters which were published in the *Philosophical Transactions of the Royal Society* for June, 1693 (pages 781–95), November, 1693 (pages 941–8), December, 1693 (pages 978–98), and May, 1694



Photograph by the Nordiska Museet, Sweden

DRUG JARS AND APPARATUS FROM THE OLD APOTHECARY SHOP OF CARL W. SCHEELE, KÖPING, SWEDEN, AND NOW EXHIBITED IN THE NORDISKA MUSEET, STOCKHOLM

(pages 121–35). These letters, which were evidently prepared from notes taken in Virginia were written at wide intervals. The first two bear the dates of May 12, 1688, and August 17, 1688; the remaining two are dated November 24, 1693, and May 22, 1694.[9]

As to the remaining events of Clayton's life, very little is known. After serving as Rector of Crofton at Wakefield, he became dean of the Protestant Cathedral Church of Kildare, Ireland, where in all probability he

[9] Except the first letter of May 12, 1688, these are still preserved among the manuscripts of the Royal Society, where there is also a fifth unpublished one-page letter of Clayton dated June 20, 1694. This mentions the sending of a mineral and describes a method of subliming sulfur; it does not belong to the Virginia series of letters.

died. Among the papers found after his death were several unpublished manuscripts which were transmitted by the Reverend Robert Clayton,[10] Lord Bishop of Cork, to the Royal Society and published in Volume XLI of the *Philosophical Transactions* (1739–40). These papers comprise:

"An experiment concerning the Spirit of Coals," part of a letter written by Rev. John Clayton, D.D., to the Hon. Robert Boyle (pages 59–61).

"An experiment concerning the nitrous particles of the air" (pages 62–3).

"A letter from Revd. Mr. John Clayton (afterwards Dean of Kildare in Ireland) to Dr. Grew in answer to several queries relating to Virginia, sent to him by that learned Gentleman A.D. 1687." (Interesting for Clayton's account of the herbs used as medicines by the Indians of Virginia) (pages 143–62.)

"An experiment to prove that water, when agitated by fire is infinitely more elastic than air in the same circumstances" (pages 162–6).

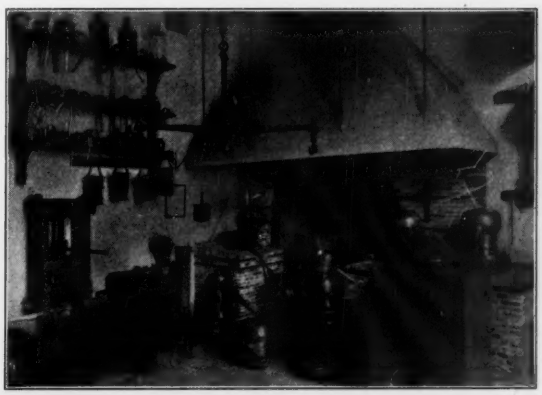
The remainder of this paper is devoted to a few quotations from Clayton's writings. Those who are familiar with the writings of Boyle, Hooke, Grew, Mayow, and other members of the Royal Society of Clayton's time will recognize the similarity of language

Photograph by Mrs. C. A. Browne

LAJONET APOTHECARY SHOP, UPPSALA, SWEDEN. A TABLET ON THE WALL OF THE HOUSE STATES THAT CARL W. SCHEELE LIVED AND WORKED HERE BETWEEN 1770 AND 1775

and ideas. The first quotation relates to Clayton's examinations of the waters and springs of Virginia; his observations on this subject stamp him as the pioneer scientist of the Colonies in this particular field. His use of color indicators and of specific gravity determinations are worthy of note. Clayton's application of these methods to urinary analysis was a natural result of his medical studies.

"As for the Waters in the Springs in general, they are, I think, somewhat more eager than those in England. In that I have observed, they require some Quantity more of Malt to make strong Beer than our English Waters, and will not bear Soap. I have try'd several by infusing of Galls, and have found little difference in the colours, turning much what the Colour of common Sack in Taverns. I tried two Wells at Collonel Bird's by the Falls of James River, several Wells near James Town, some Springs in the Ille of Wight County: There's a Spring in the Ille of Wight, or Nanzamond County, vents the greatest Source of Water I ever saw, excepting Holy-Well in Wales, but I had not Opportunity to make Experiments thereof. I tried likewise some Springs on the Banks of York River, in New Kent and



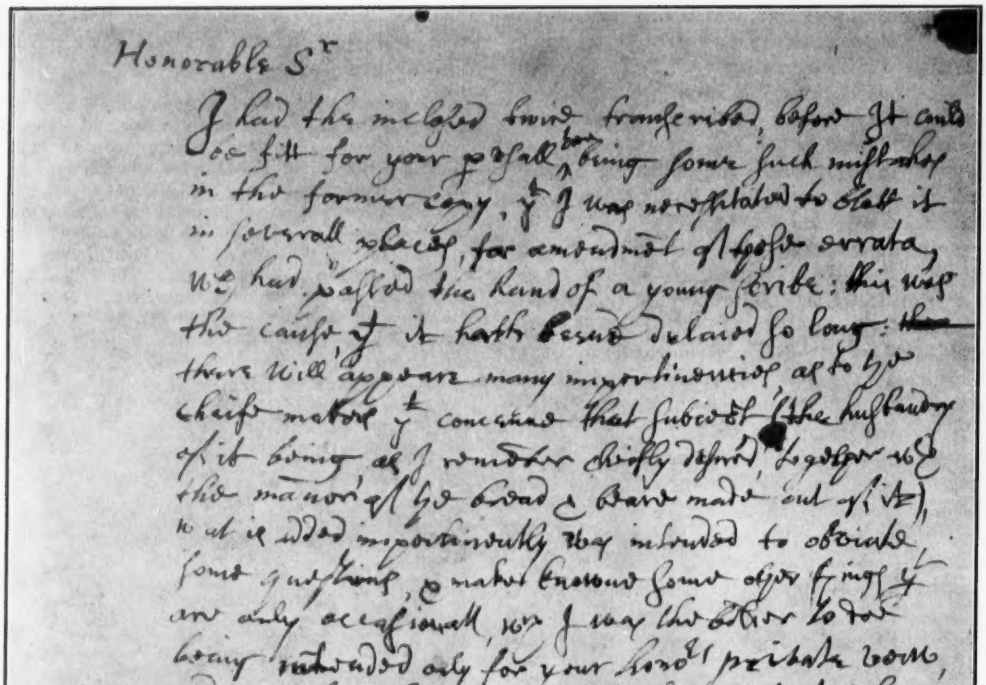
Photograph by the Amsterdam Stedelijk Museum

OLD CHEMICAL LABORATORY OF THE SECOND HALF OF THE 18TH CENTURY. MUNICIPAL MUSEUM, AMSTERDAM

Glocester County, but found them vary very little as to Colour. I could not try any thing as to their specifick Gravity, having neither Aquapoise, nor those other Glasses I had contrived peculiarly for making such Experiments, they being all lost with my other things. I had Glasses blown would hold about five Ounces, others about ten Ounces, with Necks so small, that a Drop would make a considerable Variation; with these I could make much more critical and satisfactory Observations as to the specifical Gravity of Liquors, having critical Scales, than by any other Way yet by me tried. I used this Method to weigh Urines which Practice I would recommend to the inquisitive and critical Physicians. I had made many Observations hereof, but all Notes were likewise lost with my other things. Yet I had begun afresh; for there are more signal Variations in the Weights of Urines than one would at first imagine; and when the Eye can discover little, but judge two Urines to be alike, they may be found to differ very much as to Weight. By Weight I find Observations may be made of Affections in the Head which rarely make any visible Alterations in the Urine. I have found two Urines not much unlike differ two and twenty Grains in the Quantity of about four or five Ounces: But let them that make these Essays weigh all their Urines when cold, lest they be thereby deceiv'd."

Clayton's remarks upon the soils of Virginia are also of interest and represent, so far as the writer has been able to determine, the earliest work of any American investigator in the field of soil science. His proposal

[10] The Reverend Robert Clayton (1695–1758) was the son of Dr. Robert Clayton, Minister of St. Michael's, Dublin, and dean of Kildare. Since Rev. John Clayton was also dean of Kildare he very probably belonged to the same branch of Claytons as the famous Lord Bishop of Cork who edited his posthumous papers. In a note to the papers sent by the Lord Bishop to the Royal Society he states that these were all he "could save intire out of a great number which were sent to the Hon. Mr. Boyle, in answer to a letter from him to Mr. John Clayton containing 17 Quaeres." Rev. John Clayton may also have been related to the Claytons of Virginia, a circumstance that might possibly explain his visit to Jamestown in 1684.



Honorable Sr

I had the inclosed twice transcribed before it could be fitt for your perusall there being some such mistakes in the former copy; that I was necessitated to blott it in several places for amendment of those errata which had passed the hand of a young scribe: this was the cause that it hath beene delaied so long: there will appeare many importinencies as to the chiefe matters that concerne that subject (the husbandry of it being as I remember chiefly desired together with the matters of the bread and beare made out of it), what is added importinently was intended to obviate some questions and make knowne some other things that are only occasionable which I was the better to doe being intended only for your honorable's private views and an other honorable friend then present when I had your commands about it: you may be pleased to pick out what may be pertinent to the matter of the discourse and the rest or any thing unsuitable will be fitt to be obliterated that there may be the best satisfaction to your honour from my part; its all that was intended and desired by

Your much obliged and most
humble servant
John Winthrop

London
July 29, 1662

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LETTER OF JOHN WINTHROP TO ROBERT BOYLE OF JULY 29, 1662, TRANSMITTING THE CORRECTED MANUSCRIPT OF AN ARTICLE ON THE USES OF MAIZE, WHICH WAS LATER PUBLISHED IN THE *Philosophical Transactions of the Royal Society*.

to use color indicators on soils is an early anticipation of pH measurements, and his correlation of the quality of the crop with the nature of the soil is directly in line with modern conceptions. His reflections on filtration of plants take us at once into the perplexing subject of assimilation and plant nutrition.

"The Soil in general is sandy: I had designed, and I think it might be worth a critical Remark, to observe, the difference of Soils seem appropriated to the several Sorts of Tobacco: For there is not only the two distinct Sorts of a sweet-scented, and Aranoko Tobacco, but of each of these be several Sorts much different, the Seeds whereof are known by distinct Names, they having given them the Names of those Gentlemen most famed for such Sort of Tobacco, as of Prior Seed, etc. Nay, the same Sort of Seed in different Earths, will produce Tobacco much different, as to Goodness. The richer the Ground, the better it is for Aranoko Tobacco, whose Scent is not much minded, their only Aim being to have it specious, large, and to procure it a bright Kite's Foot Colour. Had not my Microscopes, etc., Tools to grind Glasses, been cast away, with my other things, I had made some critical Enquiries into their several Natures, I would have examined what Proportions of Salts, all the Sorts of Earths had afforded, and how Water impregnated with their Salts, would have changed with infusing Galls, how with the Syrup of Violets, and how they would have precipitated Mercury, or the like, and so far forth as I had been able, examined them by the several Tryals of Fire. I conceive Tobacco to be a Plant abounding with nitrosulphureous Particles; for the Planters try the Goodness of their Seed, by casting a little thereof into the Fire; if it be good, it will sparkle after the Manner of Gunpowder: So will the Stalks of Tobacco-leaves, and perhaps has something analagous to the narcotick Sulphur of Venus, which the Chymists so industriously labour after. The World knows little of the Efficacy of its Oil, which has wonderful Effects in the curing of old inveterate Sores, and scrophulous Swellings, and some, otherwise applied and qualified. The Goodness of Tobacco I look on primarily consists in the Volatility of its Nitre: And hence the sandy Grounds that are most impregnated therewith, and whose nitrous Salt is most volatile, for such Grounds are quickliest spent, yield Tobacco's that have the richest Scent and that shortly become a pleasant Smoak; whereas, in Tobacco that grows on stiff Ground, the Salts seem more fix'd, and locked up in the Oyl, so that whilst new, 'tis very heady and strong, and requires some time for its Salts to free themselves, and become volatile; which it manifests, by its having an urinous Smell. The same reason satisfies, why Tobacco that grows on low Lands as far as the Salts, tho' the Plant be never overflowed with salt Water, yet the Ground that feeds the Plant being impregnated with salt Water, that Tobacco smoaks not pleasantly, and will scarcely keep Fire; but do all that a Man can, will oft go out, and give much trouble in frequent lighting the Pipe, 'till after it has been kept some considerable Time: Which may be assign'd to the more fixt saline Particles of the marine Salt in these Plants; which require more time ere they be rendered volatile. Here it might be worthy of an Enquiry into the nature of Filtration of Plants, since we may hence gather, Particles of the marine Salt are carried along with the Succus Nutritius of the Plant; concerning which, if it were not too much to deviate from the Matter in hand, I should offer some Reflections of my own, which the learned Society might perhaps improve."

Clayton's experiments on the clays of Virginia and his allusion to its iron ores have an industrial chemical interest and indicate the very practical nature of his survey of the Colonies' natural resources.

"I have found Veins of Clay, admirable good to make Pots, Pipes or the like of, and whereof I suppose the Indians make their Pipes, and Pots, to boil their Meat in, which they make very handsomely, and will endure the Fire better than most Crucibles: I took of this Clay, dryed, powdered, and sifted it; powdered and sifted Potsherds and Glass; three parts, two parts and one part as I remember, and therewith made a large Crucible, which was the best I yet ever tried in my Life; I took it once red hot out of the Fire, and clapt it immediately into Water, and it started not at all. The Country abounds mightily with iron Oar, that as I have been assured by some upon Tryal, has been found very good. There are Rocks thereof appear at the precipice of Hills, at the foot whereof there runs a River fit for a Forge, and there's Wood enough to supply it with Charcoal; as I have heard there was formerly some Persons undertook the Work, and when they had made but a small Quantity of Iron, which proved very good, the Indian Massacre happened, and they being higher seated than the then inhabited Part of the Country, were all cut off, and the Works demolished; so that it has frighted others I think from the like Attempt; besides, such a Work requires a greater Fund, and Bank of Money to carry it on, than any there are able to lay out; and for Persons in England to meddle therewith, is certainly to be cheated at such a Distance."

In his discussion of the thunderstorms of Virginia, Clayton remarks:

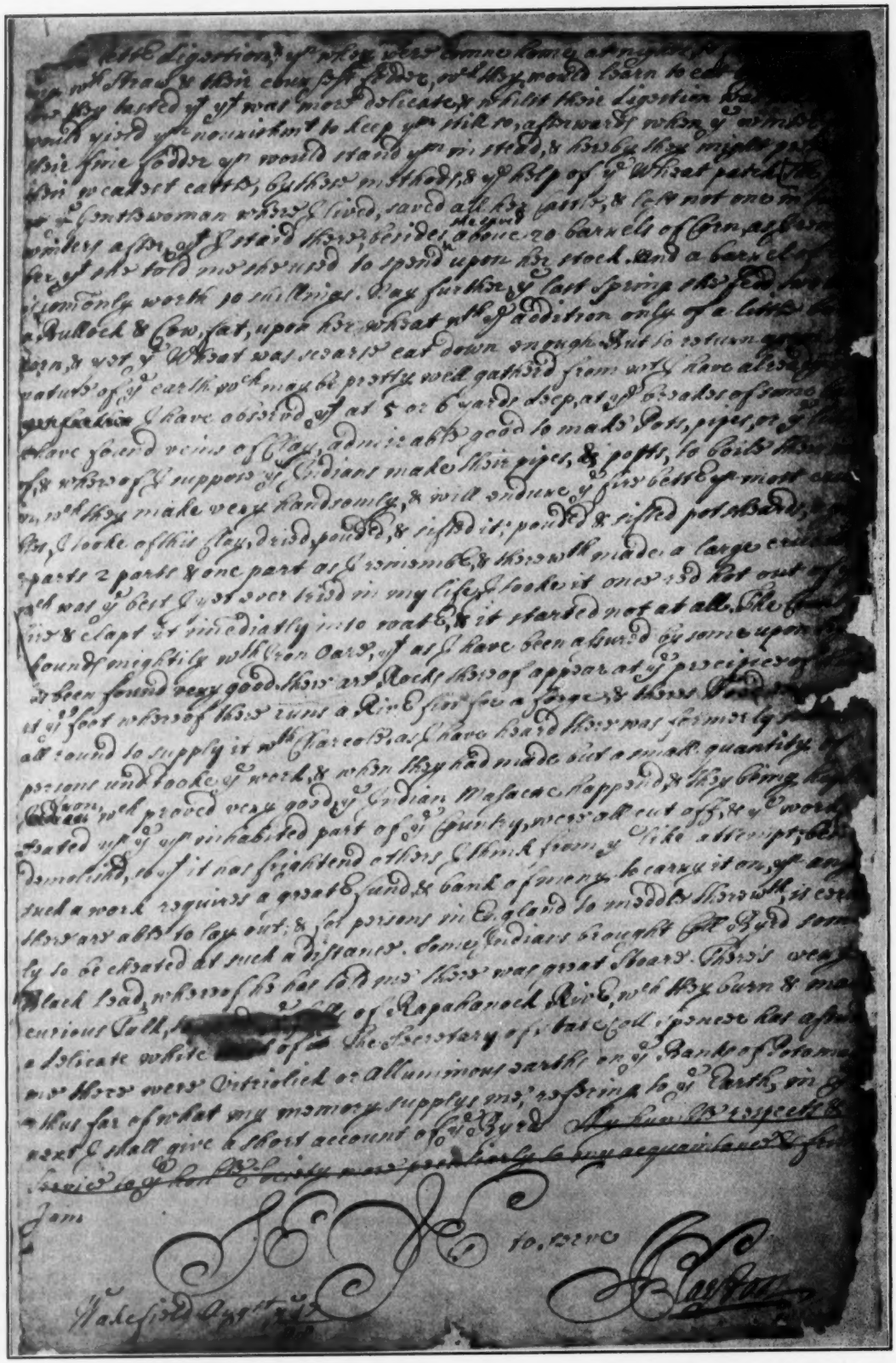
"I have been told by very serious Planters, that thirty or forty Years since, when the Country was not so open, the Thunder was more fierce, and that sometimes after violent Thunder and Rain, the Roads would seem to have perfect casts of Brimstone; and 'tis frequent after much Thunder and Lightning for the Air to have a perfect sulphureous Smell. Durst I offer my weak Reasons when I write to so great Masters thereof, I should here consider the Nature of Thunder, and compare it with some sulphureous Spirits which I have drawn from Coals, that I could no way condense, yet were inflamable; nay, would burn after they pass'd through Water, and that seemingly fiercer, if they were not over-power'd therewith. I have kept of this Spirit a considerable time in Bladders; and though it appeared as if they were only blown with Air, yet, if I let it forth, and fired it with a Match or Candle, it would continue burning till all were spent."

This passage is important as it is the earliest reference which the writer has been able to find on the production of illuminating gas from coal. The process is more fully described in Clayton's posthumous paper "An Experiment concerning the Spirit of Coals" which was part of a letter that he wrote to Boyle and was published many years later by Bishop Robert Clayton of Cork in the Philosophical Transactions of the Royal Society for March, 1739. This being the two hundredth anniversary of the publication of Clayton's paper, it might very appropriately be read on the present occasion.

AN EXPERIMENT CONCERNING THE SPIRIT OF COALS

(Part of a letter to the Hon. Rob. Boyle from the late Rev. John Clayton, D.D.)

"Having seen a Ditch within two miles from Wigan in Lancashire, wherein the Water would seemingly burn like Brandy, the Flame of which was so fierce, that several Strangers have boiled Eggs over it; the People thereabouts indeed affirm, that about 30 years ago it would have boiled a Piece of Beef; and that whereas much Rain formerly made it burn much fiercer, now after Rain it would scarce burn at all. It was after a long-continued Season of Rain that I came to see the Place, and make some Experiments and found accordingly that a lighted Paper, though it were waved all over the Ditch, the Water would not take Fire. I then hired a Person to make a Dam in the Ditch and fling out the Water, in order to try whether the Steam which arose from the Ditch would then take Fire, but found it would not. I still, however, pursued my Experiment, and made him dig deeper; and when he had dug about the Depth of half a yard, we found a shelly Coal, and the Candle being then put down into the Hole, the Air catched Fire, and continued burning.



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"I observed that there had formerly been Coal-pits in the same Close of Ground; and I then got some Coal from one of the Pits nearest thereunto, which I distilled in a Retort in an open Fire. At first there came over only *Phlegm*, afterwards a black *Oil* and then likewise a *Spirit* arose, which I could noways condense, but it forced my Lute, or broke my Glasses. Once, when it had forced the Lute, coming close thereto, in order to try to repair it, I observed that the Spirit which issued out caught Fire at the Flame of the Candle, and continued burning with Violence as it issued out, in a Stream, which I blew out and lighted again, alternately, for several times. I then had a Mind to try if I could save any of this Spirit, in order to which I took a turbinated Receiver, and putting a Candle to the Pipe of the Receiver whilst the Spirit arose, I observed that it catched Flame, and continued burning at the End of the Pipe, though you could not discern what fed the Flame: I then blew it out, and lighted it again several times; after which I fixed a Bladder, squeezed and void of Air, to the Pipe of the Receiver. The *Oil* and *Phlegm* descended into the Receiver, but the Spirit, still ascending, blew up the Bladder. I then filled a good many Bladders therewith, and might have filled an inconceivable Number more; for the Spirit continued to rise several Hours, and filled the Bladders almost as fast as a Man could have blown them with his Mouth; and yet the Quantity of Coals I distilled were inconsiderable.

"I kept this Spirit in the Bladders a considerable time, and endeavour'd several ways to condense it, but in vain. And when I had a Mind to divert Strangers or Friends, I have frequently taken one of these Bladders, and pricking a Hole therein with a Pin, and compressing gently the Bladder near the Flame of a Candle till it once took Fire, it would then continue flaming till all the Spirit was compressed out of the Bladder; which was the more surprising, because no one could discern any Difference in the Appearance between these Bladders and those which are filled with common Air.

"But then I found, that this Spirit must be kept in good thick Bladders, as in those of an Ox, or the like; for if I filled Calves Bladders therewith, it would lose its Inflammability in 24 Hours, though the Bladder become not relax at all." (*Phil. Trans. Roy. Soc.*, **41**, 59–61 (1739).)

Of Clayton's other scientific publications, reference will only be made to his interesting paper entitled, "An Experiment to prove that Water, when agitated by Fire, is infinitely more elastic than Air in the same Circumstances," which belongs to the series of articles that were salvaged for publication by Bishop Clayton after the Reverend John Clayton's death. In this report Clayton calls attention to the immense expansive power of superheated steam, and his experiment might be considered an early example of a boiler explosion. He heated a closed digester containing a pint of water over the direct fire of a grate. The explosion blew all the coals out of the grate and the main part of the digester was hurled across the room, where it shattered the leaf of an oak table. Chemical experimenting had its perils even in the early days of Clayton.

The passages quoted give only a fragmentary idea of the immense range of Clayton's scientific pursuits. His manuscripts in the Library of the Royal Society are of great interest to the student of early chemistry in America. His handwriting is more legible than many documents of a later date.

It is regrettable that we do not know more about Clayton's history. It is possible that a search of the records of the Cathedral Church of Kildare might disclose other particulars concerning his birth, education, life, and death, and perhaps lead to the discovery of other letters and papers that might throw additional light upon his interest in chemistry.

TRANSCRIPT FROM THE LAST PAGE OF REV. JOHN CLAYTON'S LETTER OF AUGUST 17, 1688, TO THE ROYAL SOCIETY ON THE NATURAL RESOURCES OF VIRGINIA

"But to return again to the Nature of the Earth, which may be pretty well gathered from what I have already said; I have observed, that at five or six Yards deep, at the Breaks of some Banks, I have found Veins of Clay, admirable good to make Pots, Pipes or the like of, and whereof I suppose the Indians make their Pipes, and Pots, to boil their Meat in, which they make very handsomely, and will endure the Fire better than most Crucibles: I took of this Clay, dryed, powdered, and sifted it; powdered and sifted Potsherds, and Glass; three parts, two parts and one part as I remember, and therewith made a large Crucible, which was the best I yet ever tried in my Life; I took it once red hot out of the Fire, and clapt it immediately into Water, and it started not at all. The Country abounds mightily with iron Oar, that as I have been assured by some upon Tryal, has been found very good. There are Rocks thereof appear at the precipice of Hills, at the foot whereof there runs a River fit for a Forge, and there's Wood enough to supply it with Charcoal; as I have heard there was formerly some Persons undertook the Work, and when they had made but a small Quantity of Iron, which proved very good, the Indian Massacre happened, and they being higher seated than the then inhabited Part of the Country, were all cut off, and the Works demolished; so that it has frighted others I think from the like Attempt; besides, such a Work requires a greater Fund, and Bank of Money to carry it on, than any there are able to lay out; and for Persons in England to meddle therewith, is certainly to be cheated at such a Distance; some Indians brought Col. Bird some black Lead, whereof he told me there was great Store. There's very curious Chalk towards the Falls of Rapahanock River, which they burn, and make a delicate White-wash of it. The Secretary of State Col. Spencer, has assured me, there were vitriolick or alluminous Earth on the Banks of Potomack. And thus far of what my Memory supplies me, referring to the Earth; in the next I shall give a short Account of the Birds."

LATIN *and* GREEK ROOTS *in* CHEMICAL TERMINOLOGY

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IN AN address delivered at the Williams Memorial, Cornell University, April 23, 1937, Armin O. Leuschner of the University of California remarked, "Not only did the founders (of Sigma Xi) get their letters and motto from classical men, but ever since, science has used the Latin and Greek language as its mode of expression in designating its fields of endeavor, and within the fields, their subjects of study and the

contents of its body of learning, such as astronomy, geology, genetics, and so forth. The scientific student is often at sea as to the meaning of words flung at him in lectures or printed in books. The professor of science is as a rule unable to give the derivations of the technical terms which he uses. We speak of the dead languages, but it is the scientist that keeps them alive, chiefly because of the clearness with which he may express himself with the use of words of Greek and Latin roots."[1]

To help the chemist, whether professor or student, become a better etymologist and thus remedy the situation above referred to, the following list of Latin and Greek roots has been compiled. It is by no means complete, but it is believed that those roots most frequently used have been incorporated. Exercise in the use of the table will quickly render one proficient in the analysis of complex chemical terms which are encountered in the literature and have been synthesized from the simpler words of the ancient classics. Thumbing of an unabridged dictionary will convince anyone that modern scientific terminology is founded almost exclusively upon the Latin and Greek languages.

To increase the legibility and simplify the typographic work, Greek characters have been transliterated. The letters L and G indicate Latin and Greek origin, respectively.

Root	*Source*		*Meaning*	*Examples*
a-	a-	G	without	amorphous
acet-	acetum	L	vinegar	acetic
acicul-	acicula	L	little needle	acicular
acroö-	a-chromos	G	colorless	acroödextrin
actin-	aktis	G	ray	actinium
adip-	adeps	L	fat	adipic, adipose
adsorp-	adsorbeo	L	draw towards	adsorption
aetio-	aitia	G	cause	aetioporphyrin
alb-	albus	L	white	albumen
allia-	allium	L	garlic	alliaceous
allo-	allos	G	different, other	allotropic
alumin-	alumen	L	alum	aluminum
ampho-	ampho	G	different, other	amphoteric
amygdal-	amydala	L	an almond	amygdalin
amyl-	amylum	L	starch	amylodextrin
an-	ana	G	up	anode
antho-	anthos	G	flower	anthocyans
anti-	anti	G	opposite, against	syn- and anti- forms
aqua	aqua	L	water	aqueous
argent-	argentum	L	silver	argenticyanide
argon	argon	G	inactive	argon
aster-	aster	G	star	asterism
atom-	atomos	G	undivided	atomic
auro-	aurum	L	gold	aurous, aurin
auto-	autos	G	self	auto-oxidation
auxo-	augeo	L	to increase	auxochrome
bar-	barus	G	heavy	barium, barometer
batho-	bathos	G	deep	bathochrome
bi-	bis	L	twice	bisulfate
bio-	bios	G	life	biochemistry
brevium	brevis	L	short	brevium
brom-	bromos	G	stench	bromine
cacodyl-	kakodes	G	ill-smelling	cacodylic
cadav-	cadaver	L	corpse	cadaverine
caes-	caesius	L	sky-blue	caesium
caesium	caesius	L	bluish-gray	caesium
calcium	calx	L	lime	calcium, calcite
calor-	calor	L	heat	calorie, calorimeter
capill-	capillus	L	hair	capillary
capr-	caper	L	goat	capric, caproic
carbo-	carbo	L	coal	carbon, carbide
case-	caseus	L	cheese	casein
cata-, cath-	kata	G	down	cathode, cation
celest	celestis	L	heavenly	celestite
centi-	centum	L	hundred	centimeter
cephal-	cephale	G	head	cephalin
cerebro-	cerebrum	L	brain	cerebrosides
cet-	cete	L	whale	cetyl
chalco-	chalkos	G	brass	chalcopyrite
chlor-	chloros	G	greenish yellow	chlorine, chlorophyll
chol-	chole	G	bile	cholic, cholesterol
-chore	chore	G	volume	isochore, parachor
chrom-	chromos	G	color	dichromic, chromium
chryso-	chrysos	G	golden yellow	chrysoberyl
citr-	citrus	L	citron tree	citric
-clast	klastein	G	to break	proteoclastic
-clinic	clino	G	to lean	triclinic
coagulat-	coactum	L	driven together	coagulation
colloid-	kolla	G	glue	colloidal
conchoid-	concha	L	shell-like	conchoidal
cono-	conos	G	cone	conoscope
cosmo-	kosmos	G	world	microcosmic
creat-	kreas	G	meat	creatine
croceo-	croceus	L	saffron-yellow	croceo-salt
cruor-	cruor	L	blood	cruorin
cryo-	cryos	G	cold, frost	cryoscopic
crypto-	kryptos	G	hidden	cryptocrystalline
cupr-	cuprum	L	copper	cupric, copper
cyan-	cyanos	G	deep blue	cyanide, hemocyanin
cyclo-	kuklos	G	circle	heterocyclic
cyto-	cytos	G	cell, hollow	cytochrome
deca-	deka	G	ten	decahydrate
decrepit-	de-crepare	L	to creak, rattle	decrepitation
deliques-	liquescere	L	to become fluid, melt	deliquescent
dendr-	dendron	G	tree	dendritic
des-	de-	L	indicates privation	desoxybenzoin
desmo-	desmos	G	a bond	desmotropism
deuter-	deuteros	G	second	deuterium
dextro-	dexter	L	right	dextrose
di-	dis	G	twice	dichromate
diabatic	diabaino	G	to go through	adiabatic
ditrigon-	di-trigonos	G	twice three-cornered	ditrigonal
dodec-	dodeka	G	twelve	dodecane
dulci-	dulcis	L	sweet	dulcitol
dynam-	dynamis	G	power, force	thermodynamics
dyspros-	dysprositos	G	hard to get at	dysprosium
efflores-	efflorescere	L	to blossom, bloom	efflorescent
emanat-	emanare	L	to flow out	emanation
en-, endo-	en, endo	G	within, inside	endothermic
enantio-	enantios	G	opposite	enantiomorphic
enzym-	en-zyme	G	in yeast	enzymic

[1] *Sigma Xi Quarterly*, 25, 2, 70 (1937).

Root	*Source*		*Meaning*	*Examples*
eos-	eos	G	dawn	eosin
-eresis	aireo	G	to draw	syneresis
erythro-	erythros	G	red	erythrodextrin
eu-	eu	G	well, easily	eutectic
exfoliat-	ex, folium	L	out, leaf	exfoliation
exo-	ex	G	outside, out of	exothermic
fer-	fero	L, G	to carry	argentiferous
ferro-	ferrum	L	iron	ferrocyanide
fili-	filum	L	thread	filiform
flavo-	flavus	L	yellow	flavo-salt
flocc-	floccus	L	flock of wool	flocculent
fluor-	fluere	L	to flow	fluorescence, fluorine
furfur-	furfur	L	bran	furfural
Galli-	Gallia	L	France	Gallium
gen-	genao	G	to produce, make	ionogen, hydrogen
glu(y)co-	glukos	G	sweet	glucose, glycogen
halo-	hals	G	salt	halogen, halide
helio-	helios	G	the sun	helium
hemi-	hemi	G	a half	hemihydrate
hemo-	haima	G	blood	hemocyanin
hepta-	hepta	G	seven	heptane, heptose
hetero-	heteros	G	other, different	heterocyclic
hexa-	hex	G	six	hexahydrobenzene
hippo-	hippos	G	horse	hippuric
histo-	histion	G	tissue	histidine
homo-	homos	G	same	homologous
horde-	hordeum	L	barley	hordein
hydro-	hudor	G	water	hydrate, hydrogen
hygro-	hygros	G	wet, moist	hygroscopic
hypo-	hypo	G	under, lower than	hypochlorous
indium	Indium	L	indigo-blue	Indium
infra-	infra	L	beneath	infra-red
intumesc-	intumescere	L	swell up	intumescence
iodo-	iodes	G	violetlike	iodine
irid-	iris	G	rainbow	iridium, iridescent
iso-	isos	G	similar	isotope, isomorphic
kinet-	kinesis	G	a moving	kinetic
krypton-	kryptos	G	hidden	krypton
kyn-	kynos	G	dog	kynurenic
lac-	lac	L	milk	lactose, lactic
lamell-	lamina	L	plate	lamellar
lanthan-	lanthanein	G	to be concealed	lanthanum
leuco-	leukos	G	white	leuco-base
levo-	laevus	L	left	levulose, *l*-form
lign-	lignum	L	wood	lignocellulose
lipo-	lipos	G	fat	lipoid, lipolytic
lithium	lithos	G	stone	lithium
lumin	lumen	L	light	luminescence
lutecium	lutetia	L	Paris	lutecium
-lytic -lysis	luo	G	decompose	hydrolytic, -lysis
macro-	makros	G	large	macroanalysis
mal-	malum	L	apple	malic
malle-	malleus	L	hammer	malleable
melan-	melas	G	black	melanin
mell-	mel	L	honey	mellitic
-mer	meros	G	a part	isomer, tautomer
meso-	mesos	G	middle	mesoxalic
metabol-	metabole	G	alter	metabolic
micro-	mikros	G	small	microanalysis
mimet-	mimesis	G	imitation	mimetic
molecule	molecula	L	a small body	molecule
mono-	monos	G	one, single	monobasic
mord-	mordeo	L	bite, eat into	mordant
morph-	morphe	G	form	isomorphic
muta-	muto	L	change	mutarotation
neon-	neos	G	new	neon
nephelo-	nephele	G	a cloud	nephelometry
nitro-	nitrum	L	native soda	nitrogen
nona-	nonus	L	ninth	nonane
octa-	octo	L, G	eight	octane
-ode	hodos	G	road	anode, cathode
ole-	oleum	L	oil	oleic
osmium	osme	G	smell	osmium
oxy-	oxus	G	bitter, acidic	oxygen
pect-	pektos	G	congealed	pectin
pent-	pente	G	five	pentoxide
peps-	pepsis	G	digestion	peptize, pepsin
per-	per-	L	excess, more	perchloric
petr-	petra	L	rock	petroleum
phanero-	phanein	G	to be visible	phanerocrystalline
-phile	phileo	G	to love	lyophilic
phlogiston	phlogisteo	G	to set on fire	phlogiston
-phobe	phobia	G	fear	lyophobic
phor-	fero	L, G	to carry	cataphoresis
phos- photo-	phos	G	light	photosynthesis
-phyll	phyllon	G	leaf	chlorophyll
phyto-	phyton	G	plant	phytosterols
picric	pikros	G	bitter-	picric
piezo-	peizein	G	to exert pressure	piezochemistry
pinaco-	pinako-	G	mirror image	pinacol
piper-	piper	L	pepper	piperazine
pleo-	pleio-	G	many, more	pleochroism
plumb-	plumbum	L	a leaden ball	plumbite
porphyr-	porphyra	G	purple	hematoporphyrin
potential	potentia	L	power	potential
praeseo-	prasios	G	leek-green	praseodymium praeseo-salt
proteo-	proteos	G	original	proteolytic
pseudo-	pseudos	G	false	pseudo-alums
pulver-	pulvis	L	dust	pulverulent
pycno-	puknos	G	dense	pycnometer
pyro-	pur	G	fire	pyrophosphate
quantum	quantum	L	how much	quantum mechanics
quatern-	quater	L	four times	quaternary
racem-	racemus	L	cluster	racemic
ren-	renes	L	kidneys	adrenalin
retic-	rete	L	net	reticulated
rhodium	rhodon	G	a rose	rhodium
rub-	ruber	L	red	bilirubin, rubidium
salic-	salix	L	willow	salicylic
sarco-	sarkos	G	of flesh	sarcosine
sclero-	skleros	G	hard	scleroprotein
selen-	selene	G	moon	selenium, selenide
semi-	semi-	L	half	semihydrate
sesqui-	sesqui-	L	one and a half	sesquioxide
silic-	silex	L	a flint	silicon, silicate
solut-	solutum	L	dissolved	solution
solv-	solvens	L	dissolving	solvent
sphenoid-	sphen	G	a wedge	sphenoidal
stalact-	stalaktos	G	oozing in drops	stalactite
stann-	stannum	L	tin	stannic
stereo-	stereos	G	volume, space	stereochemistry
stero-	stear	G	tallow	stearic
stib-	stibium	L	antimony	stibine
striat-	stria	L	furrow	striated
succin-	succinum	L	amber	succinic
sucr-	sucrum	L	sugar	sucrose
super	super	L	above	superphosphate
syn-	syn	G	with, on same side	syn- and anti- form
synthet-	syn, tithemi	G	to put together	synthetic

Root	*Source*		*Meaning*	*Examples*
tauto-	tautos	G	same	tautomeric
tect-	teko	G	melt	eutectic
tellur-	tellus	L	earth	tellurium
ter-	ter	L	three times	terchloride
tetra-	tessares	G	four	tetroxide
thallium	thallos	G	green twig	thallium
thalp-	thalpos	G	heat, warmth	enthalpy
thermo-	thermos	G	heat	thermoluminescence
thio-	theios	G	sulfur	thiosulfate
thixo-	thixis	G	touch	thixotropic
topo-	topos	G	place, arrangement	isotope
tri-	tres	L	three	trimethylamine
tribo-	tribo	G	rub	triboluminescence
trop-	trepo	G	turn, change	allotropic
trunc-	truncatus	L	cut off	truncated
ultra	ultra	L	beyond	ultraviolet
undec-	undecim	L	eleven	undecane
uni-	unus	L	one	univalent
vitr-	vitrum	L	glass	vitreous
xantho-	xanthos	G	yellow	xanthoproteic
xenon	xenos	G	stranger	xenon

Prefixes employed by the chemist to designate the numbers of atoms or radicals in a molecule, the number of molecules of water of crystallization, and so forth, are all taken literally from the Latin or Greek. It would well pay any student of chemistry to commit to memory the lower numerals:

	Latin	*Greek*
1	unus	eis
2	duo	duo
3	tres	tres
4	quattuor	tessares
5	quinque	pente
6	sex	hex
7	septem	hepta
8	octo	okto
9	novem	ennea
10	decem	deka

Letters of the Greek alphabet are employed by chemists, physicists, and mathematicians.

Alpha	α	A	Nu	ν	N
Beta	β	B	Xi	ξ	Ξ
Gamma	γ	Γ	Omicron	o	O
Delta	δ	Δ	Pi	π	Π
Epsilon	ϵ	E	Rho	ρ	P
Zeta	ζ	Z	Sigma	σ	Σ
Eta	η	H	Tau	τ	T
Theta	θ	Θ	Upsilon	υ	Υ
Iota	ι	I	Phi	φ	Φ
Kappa	κ	K	Chi	χ	X
Lambda	λ	Λ	Psi	ψ	Ψ
Mu	μ	M	Omega	ω	Ω

The use of the terms *ortho*, *meta*, and *para* to designate the positions of elements or groups in disubstituted benzene is purely conventional, as *ortho* and *para* both signify *alongside of*. More exactly, an interchange of the two terms would better preserve their original meaning, for primarily *para* means *alongside of* and *ortho*, *straight*. *Meta* signifies *in the midst of* or *between*, and is hence properly used to designate the position between ortho and para. Whether *ortho* and *para* were chosen well or poorly, it is not ours to question; it has always been the privilege of the discoverer to name his find as he pleases. In his *Ars poetica*, Horace has well said that the builders of a language give to its words the meaning, we are at liberty to do so, for not even the time-honored words of a language are immutable:

> "..... *cadentque quae nunc sunt in honore vocabula, si volet usus, quem penes arbitrium est et jus et norma loquendi.*"
> (Lines 70–72)

The STUDENTS APPRAISE *the* INSTRUCTOR[1]

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IN RECENT years, the status of the student has undergone a slow but far-reaching change. Before the onset of modern trends in education his position was well defined. He went to school aware that it was his obligation to learn something and that the professor was the one who would direct him in the attainment of knowledge. Today that obligation has been shifted from the shoulders of the students to that of the teacher. Now it is the teacher who takes the

[1] Presented before the Educational Group and the Student Associate Group of the Chicago Section of the A. C. S., June 23, 1939.

responsibility of seeing that his students learn something. Numerous schemes and methods have been devised which were to be more effective in aiding the student to acquire a more complete and thorough understanding of the subject he is studying. This desire on the part of educators to increase efficiency in learning brought the student out in a new light. His opinions are closely watched, tabulated, and studied to find weak points in a particular method of teaching. He was even asked to rate his instructors as to their ability to teach, knowledge of subject, and reliability. Such ratings call attention to certain undesirable attitudes and features of instruction, courses of study, and personality of the teacher. Ratings by students of their teachers have thus become an instrument by which the capability of an instructor may be gaged.

This friendly appraisal is unique in so far as it is not based, as all previous have been, on any questionnaire filled out by the students. The opinions and ideas that will be taken into consideration were expressed in frank discussions of their teachers by members of this group, and as the movie producers would put it, "any similarity to actual persons, living or dead, is purely coincidental." Whether these views are good or bad, whether they have any legitimate claim to recognition by educators and teachers is not our problem at the present time. This is, as it were, a public hearing to which the student should be entitled occasionally. However, it should not be inferred that, at the same time the instructors will be put on trial, the prime purpose being to bring out a few points which would make for a better understanding between the two groups.

Obviously, the first prerequisite of a person who is to teach any course in high school or college is adequate academic training. The word "adequate," however, does not mean the mere acquisition of a string of degrees plus exposure to a required number of education courses. In preparing himself for the educational field the prospective teacher should keep in mind that he is making ready to shoulder a responsibility too great to allow indifference in the preparatory period. He must acquire in that time a thorough knowledge of his field, and to be able to present that knowledge with confidence and clarity, he should be well grounded in at least the fundamentals of the technic of teaching. Because of the very nature of teaching chemistry, or for that matter any science, he will become more effective in the use of that technic as the years of his experience become more numerous.

The students generally take it for granted that the professor has sufficient background, training, and experience to lecture a particular course in chemistry. If his training and experience have been concentrated in a field other than that which he is teaching, the students do not mind if the instructor keeps two or three lectures ahead of them, provided that the presentations are well organized. If he is a physical chemist, he may be forced to review, read, and study, but he will never rely merely on experience he may have had in organic chemistry to carry him through.

In the opinion of the students the most important qualification, granted that the instructor has a thorough insight of the field he undertakes to teach, is his ability to organize the subject matter of a course. Factual material from which principles may be derived should be presented in a logical sequence. Before acquainting the student with the research being done in any field, the teacher should be reasonably certain that the fundamental principles involved are understood by the students. This tendency to overemphasize work being done by research men is apt to confuse the average student. Not until he obtains a broader knowledge and more experience in chemistry can he fully evaluate such work. This is not to say that no current research should be included in a course. As the student progresses, his familiarity with the strides being made in chemistry, especially the field which interests him most, should increase proportionally.

Instead of organizing a course himself the instructor has another alternative. He can follow the matter as it is presented in a textbook. In such a case the ideas will probably be given in a logical sequence, but if he follows the book too faithfully, the confidence and trust of the student in his teacher's knowledge of the subject is considerably lessened. The student will get much more of the matter, if lectures follow an assignment of pre-reading certain sections. The textbook should supplement the professor's lectures, but never supplant them. Otherwise he fills no definite purpose. The student would learn just as much by reading the textbook at home. The student looks for a critical discussion of the subject he is learning, rather than enumeration of definitions and data.

In his desire to give the students a thorough course the instructor may easily go to the other extreme of overorganization. He will give a jumble of outlines, references, and a mass of mimeographed material which supposedly are to direct the student to a more complete knowledge of the subject. Such procedure, however, only plays at cross purposes. Instead of aiding the student he is confronted with a task which is not only useless to ask him to perform, but for which there is no logical need. References given in moderate doses serve a very definite purpose, but no one can expect a college freshman to delve into the literature and look up references ranging from inorganic preparations to atomic structures and profit by it. For example, in a course in consumer chemistry given in a high school no less than thirty pages of references were given, listing more than five hundred books. Just what the teacher expected of the student is hard to say.

It is to be realized that any classification of instructors into sharp and distinct groups is at best arbitrary. The same instructor may have qualities and shortcomings which are predominantly satisfactory, but still fall short of being acceptable. An attempt will be made here to enumerate and discuss a few of the more outstanding categories into which the majority of instructors may be divided. With reference to type and personality, they are, *first*, the impersonal dis-

pensor of information, *second*, the high-pressure research type, *third*, the instructor who has a thorough knowledge of the subject but is unable to teach it, and *fourth*, the desirable instructor.

The average student does not look upon the instructor merely as a medium through which he can obtain factual material and other information which chemistry has to offer. In that respect the attitude of the teacher determines to a very large extent the outlook that the student will develop toward the subject. Since chemistry is a science based upon principles derived from a study of physical phenomena, it is necessary that the student be acquainted with them, but to overemphasize a single phase of the science, as is often done, defeats its own purpose. Such an instructor has come to the conclusion, after teaching many years, that the more information the student has at his fingertips, the more definite and concrete is his knowledge of the science. Closely related to this type is the instructor who goes on teaching year after year the same course, usually high-school or college chemistry, using the same lecture notes, with slight changes made to keep on the safe side of his colleagues, and telling the same stories during the lectures. He is the type who reads the textbook to the students, explaining a sentence here and there, often digressing from the topic at hand without much provocation. For him only the faces of the students change. No new problems arise. Both of these fail to arouse in the student any interest in the subject, and do not encourage original thought. One offers no incentive to study, the other because of his lethargic attitude, is incapable of stimulating the student. The brighter students find both disappointing.

The high-pressure research type, on the other hand, presents a contrast in activity. His lectures are dissertations on the more complex phases of chemistry. Even though they be organized, he is apt at times to ramble, especially if the topic is related to the field in which he has done, or is doing his research. The student does not object to being subjected to such methods, provided he is in a position to benefit by them. If such an instructor, who is so absorbed in a single aspect of a science, happens to teach freshmen or sophomores in college, the students will soon develop an inferiority complex toward chemistry and may even be discouraged from a further study of it. This type of instructor will invariably single out one or two of the brighter students, giving them more of his time with the prospect of having them do their postgraduate research under his guidance. He rarely visits the undergraduate laboratory, leaving its supervision almost entirely in the hands of his laboratory assistants. The students look upon him with respect and the awe with which he has surrounded himself. He often has no idea whether or not the matter is assimilated by the students, because he makes no effort to find out. The surprising thing is that he seldom organizes the course work with the meticulous care with which he organizes his research. To him the college or university is a place for research and research students. He forgets that his primary purpose is to teach, and that it is just as important to teach chemistry and logical thought to medical students as to a future Ph.D. in chemistry. In this category falls a large group of the staffs of our universities.

The third type of instructor is the one who knows his matter well, but because of certain traits of personality or manner of presentation of the material is incapable of teaching the course effectively. It does not take long to recognize such an instructor. His lectures, though they may be prepared and organized, are delivered poorly and in a disinterested fashion. The student who sleeps through such lectures is not to blame. If he takes the trouble to keep awake, he will find that the instructor is able to give at least the fundamentals of the course. The instructor who lectures too rapidly also presents an obstacle. The student can hardly keep up with a rapid fire succession of ideas, much less try to take notes on them.

The ideal teacher is that one who so trains his students that they become increasingly independent of his instruction and guidance. He is able to stimulate interest in the student because he himself shows a deep interest in the subject, but he must not sacrifice effectiveness and thoroughness of his instruction for the sake of making the course palatable for the student. He has a sound knowledge of his field, organizes his course in a compact and concise form, and is able to present the matter with clarity and completeness. In his relations with the students he is fair, and no favoritism is shown to any of them in the class. There is no need at all for him to be a big brother to the student, making all sorts of allowances in favor of the student, in order to avoid friction which may be called to the attention of the administration.

It was planned to present at this time a statistical study of the kinds of examinations being given and methods of grading them, being used in the high schools, colleges, and universities within the Chicago area. Due to the lack of response to the survey, such data are not now available. It would be worthwhile to know:

(1) How many examinations and quizzes are given in each fundamental chemistry course, and what weight they carry.

(2) Whether there is an analysis made in an effort to ascertain whether material is being assimilated by the students, also the number of teachers who analyze and make use of such analysis in their teaching.

(3) Whether there is real preparation of the examinations on the part of the teacher.

(4) The methods of grading in practice.

In the absence of statistics covering these points, I will comment briefly on them with reference to the type of instructors mentioned earlier. Instructors who have the essential characteristics of the first group never analyze their examinations to determine to what extent the students have assimilated unnecessary trouble. The frequency with which they give reviews

and quizzes is regulated almost entirely by convenience. They may even go so far as to try a coöperative test once.

The questions of the high-pressure research professor are based on his pet topics derived from his field of research. For the most part they are seldom organized ahead of time, complicated, and ambiguous, causing a waste of time on the part of the student in figuring out just what is wanted. This fault of ambiguity in wording questions is not uncommon among a large number of instructors. Much misunderstanding could be avoided by eliminating the possibility of interpreting the questions in a way other than that desired by the teacher. The research type of instructor rarely if ever looks at the examinations, never analyzes them. Only one or two are given in a course, and from these he is supposed to be able to tell how well the student grasped the matter of the course.

The examinations of the desirable instructor, given semi-monthly, are usually objective, covering factual material, principles, and their application, and leaving little room for the student to ramble or pad his answers. This type of instructor gives examinations not for grades, but to challenge the ability of a student to meet and solve scientific problems with confidence and assurance. For the students the discussions which follow quizzes are important, because during them doubtful points are best clarified.

The methods that an instructor has at his disposal for grading a student are varied. Final grades on examinations can either be based upon an absolute system, where each question has the same numerical value, or upon a curve. The first has the disadvantage that all questions, regardless of difficulty, carry the same weight. Also, if the examination happens to be so difficult that no one earns a passing grade, which is arbitrarily set at 70, no student gets any merit for his effort. This second drawback is avoided to some extent if the grades are distributed according to the probability curve. From the point of view of most students, neither method is fair. The first has obvious deficiencies. The second gives no idea whatsoever as to the amount of knowledge that the student obtains. He is merely rated in comparison with others whose abilities may be mediocre and even poor.

The greatest injustice that an instructor can inflict upon the student is to permit personal prejudice to influence him in giving a final grade. Although the student has no means of proving definitely favoritism or discrimination against him, it is the duty of the teacher not to provide a basis for even a rumor, by playing fair with all the students. I am quite certain that there are many teachers who dislike very much to pass judgment upon their students' knowledge in the form of a numerical or alphabetical grade. True, there is no problem to decide whether the student has passed or failed, but borderline cases, as between a low A or a high B, present difficulties which are not easily settled. A student should be graded on achievement and not on effort or ability which he may never use.

The high-school teaching of chemistry should be a relatively easy matter. I say "should be," but it is not. There are perhaps more problems facing the high-school teacher than the college instructor. On the one hand, he must satisfy the educators, whose demands have resulted in putting the high-school course in chemistry on the same level with the freshman college course. On the other hand, he must satisfy the scientists who demand that the students have a thorough training in the fundamentals of chemistry. Thus, the position of the high-school teacher is still a paradox, and unnecessarily so. The objectives of a preparatory course are smothered in an avalanche of theories, technical applications, and facts which the high-school student is not in a position to correlate and interpret. In recent times another problem has come up with which the high-school teacher must cope. He must pass ninety-nine per cent. of his class. The effectiveness of the teacher is decidedly lowered. He cannot make the examinations too hard, or give too many assignments. He is forced to coddle the students into some knowledge. The finished product under such an educational system certainly cannot be acceptable as having a thoroughly sound preparation. All this does not mean that there are no excellent and stimulating high-school teachers. Many have started young students on the road to a career in science. By making science interesting, by arousing scientific curiosity in the young mind, they have given that initial impetus which often directs the student into a life work.

The position that the teacher holds in the intellectual life of the student is a strategic one. The control that he exercises in the development of the student may be the deciding factor in the future success or failure of the individual. The criticism that he gives abilities, achievement, and possibilities for the future may bring about expansion or collapse. If he constantly brings to light shortcomings of the students, criticizing them and their work, the resulting attitude is not conducive to good relations between such an instructor and the students. The teacher will find that the student is willing to accept criticism, but there is no need whatsoever to cause embarrassment by ridiculing him in front of the entire class. Instead of pointing out a student's faults in a private conference with him, such an instructor is only trying to overcome his own inferiority complex. By the time the students reach their senior year in college, they have developed certain critical capacities, and have attained some degree of maturity and good judgment. This friendly appraisal was written primarily to remind some of the instructors of that point. It is by no means complete. Only the points at the surface were brought out, and it is hoped that the instructors will occasionally throw the torch of criticism, which they use so freely on the students, on themselves. Such a procedure will, I am sure, bring about a more friendly relation between the student and instructor.

The 1938–1939 COLLEGE CHEMISTRY TESTING PROGRAM

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THROUGH the Testing Committee of the Division of Chemical Education, the American Chemical Society coöperates with the American Council on Education in constructing, each year, a test designed to measure the degree of achievement of certain objectives common to all elementary college chemistry courses.

TABLE 1

NATIONAL CHEMISTRY PERCENTILES, 1939
(Booklet Marked)

	Part I Information and Vocabulary	*Part II Problems and Equations*	*Part III Scientific Method*	*Total*	
No. cases	8705	8705	8705	8705	
No. colleges	157	157	157	157	
Mean	29.9	18.1	16.6	64.6	
Sigma	11.7	12.3	8.6	28.1	
Maximum score	68	56	50	174	
Percentile					Percentile
100	66	56	47	160	100
99	57	50	38	137	99
98	54	47	36	130	98
97	52	45	34	124	97
96	51	43	33	119	96
95	50	42	32	116	95
94	49	40	31	113	94
93	48	39		111	93
92	47	37	30	109	92
91		36	29	107	91
90	46			104	90
88	45	34	27	101	88
86	44	33		98	86
84	42	31	26	94	84
82	41	30	25	92	82
80	40	29	24	89	80
75	38	26	22	83	75
70	36	24	21	78	70
65	34	22	19	73	65
60	33	20	18	69	60
55	31	18	17	65	55
50	29	16	16	61	50
45	28	15	15	57	45
40	26	13	14	54	40
35	25	11	13	50	35
30	23	10	11	47	30
25	21	8	10	43	25
20	19	7	9	40	20
18		6	8	38	18
16	18	5		37	16
14	17		7	35	14
12	16	4		33	12
10	15	3	6	31	10
9	14		5	30	9
8		2		29	8
7	13		4	28	7
6	12			26	6
5		1	3	25	5
4	10			23	4
3	9		2	21	3
2	8	0	1	19	2
1	6		0	15	1
0	0			2	0

These percentiles are based on returns from all colleges whose report sheets were received before July 5th. The scores listed are the raw scores of students who recorded their answers in the test booklets.

The values in each column are the scores at or below which fall the percentages of the cases indicated in the columns at the extreme right and left of the page. For example, the bottom entry in the Total column shows that a score of 15 or below was made by one per cent. of the students included; or that the lowest one per cent. of elementary chemistry students achieve total scores of 15 or less, the second lowest one per cent., scores from 16 to 19, and so forth, and the highest one per cent. achieve scores above 137.

Collaborating with the members of the Testing Committee, the Coöperative Test Service, representing the American Council on Education, and fifty instructors from twenty-nine colleges and universities gave the Committee much helpful criticism and advice.

This year two tests were prepared, the first covering the usual freshman course in general chemistry, the second, qualitative analysis. These tests were printed and distributed through the Coöperative Test Service. A total of two hundred eighty-seven colleges participated in the general chemistry testing program as compared with two hundred seventy-five last year. Of this number, one hundred sixty-nine schools sent in the results for 10,237 students in time to be included in this report. Sixty-seven colleges used the Coöperative Chemistry Test in Qualitative Analysis. The provisional percentiles for this test are based upon eight hundred eighty-seven cases reported by the twenty-nine different colleges reporting the results.

I. THE COÖPERATIVE CHEMISTRY TEST (FORM 1939)

This test was constructed similarly to the 1938 test, including the same three parts: (I) Information and Vocabulary; (II) Problems and Equations; and (III) Scientific Method. Profiting by the criticisms and suggestions submitted by the users of the 1938 test, the Testing Committee revised the material included, as well as the time allotment in an effort to obtain a fairer and more serviceable examination. The problems and equations were simplified and arranged more nearly in accordance with the order of difficulty, thus giving encouragement to the poorer students. An effort was made to eliminate some of the ambiguity from the statements used as test items in Part III. Nevertheless, some instructors probably still feel that this part should have undergone further editing.

Table 1 gives the national percentiles based upon the results of 8705 students from one hundred fifty-seven colleges.[1]

[1] Two hundred eighty-seven colleges participated in the program. Of these, one hundred sixty-nine returned reports on the Report Form No. 2 in time to be included in the basic tabulations and computations. There were one hundred fifty-five in this latter group which used booklet-recorded data, and fourteen which used answer sheets. Due to an error in the Statistical Department of the Coöperative Test Service two of the answer sheet distributions slipped into the final tabulations with the test booklet data. The condensed percentiles for colleges using separate answer sheets are therefore based on results from only twelve colleges. The two answer sheet colleges will not have disturbed the national booklet percentiles to any appreciable degree, since the number of cases in these groups are only fifty-four and thirty, respectively, and both colleges have averages within two points of the national 50th percentile.

Since the 1939 test was quite similar to the 1938 test, it is of interest to compare the relative achievement on the various parts, as measured, roughly, by the ratio of the Mean Score to the Maximum Score on each part. Table 2 gives the results of this comparison.

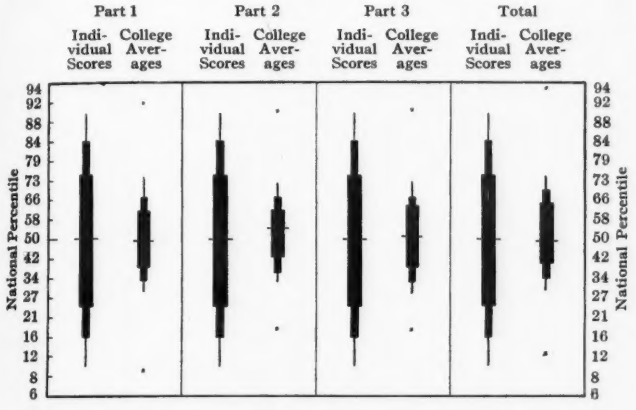

FIGURE 1.—VARIABILITY AMONG INDIVIDUAL STUDENTS AND AMONG COLLEGE AVERAGES. THE WIDE PORTION OF EACH BAR REPRESENTS THE RANGE OF THE MIDDLE FIFTY PER CENT. OF SCORES OR COLLEGE AVERAGES. THE SHORT HORIZONTAL LINE IS AT THE MEDIAN. THE NARROW PARTS OF EACH BAR EXTEND TO THE 16TH AND 84TH PERCENTILES. THE VERTICAL LINES AT THE ENDS OF THE BARS REACH TO THE 10TH AND 90TH PERCENTILES. THE CROSSES ABOVE AND BELOW THE SHORT BARS REPRESENT THE HIGHEST AND LOWEST COLLEGE AVERAGES RETURNED

TABLE 2

RELATIVE ACHIEVEMENT ON THE 1939 TEST AS COMPARED TO THE 1938 COÖPERATIVE CHEMISTRY TEST

	Part I		*Part II*		*Part III*		*Total*	
	1938	*1939*	*1938*	*1939*	*1938*	*1939*	*1938*	*1939*
Mean score	38.8	29.9	17.2	18.1	17.9	16.6	73.9	64.6
Sigma	14.8	11.7	12.4	12.3	10.8	8.6	32.3	28.1
Maximum score	91	68	70	56	65	50	226	174
$\frac{\text{Mean}}{\text{Max.}} \times 100$ %	42.7	43.9	24.6	32.3	27.5	33.2	32.7	37.1

It will be noted that the achievement on Part I showed no significant change, whereas on Parts II and III the relative achievement was appreciably higher in 1939. It is possible that this improvement was due to the simplification of those sections, as already discussed, rather than to any effort on the part of college chemistry teachers to mold their courses to fit the topics covered in this examination. To someone not acquainted with the methods of educational measurement it would appear, from the bottom row of figures, that college chemistry teachers are not giving their pupils adequate instruction or else this examination was too rigorous for the average college freshman. It must be remembered, however, that a test of this sort is constructed with the idea of measuring not only the achievement of the average student, but the capabilities of extraordinary students whose achievement cannot be measured by any test in which a pupil slightly above the average can secure a practically perfect score. One cannot determine the best high-jumper in a group of college athletes by keeping the bar set at five feet; it must be moved up in successive steps until even the best jumper cannot clear it. Viewed from this standpoint it would appear that the test was not unduly difficult, since a student made a perfect score on Part II and other students made very nearly perfect scores on Parts I and III.

Table 3 gives the percentiles based upon the results of 1532 students from twelve colleges using separate answer sheets instead of writing the answers directly in the test booklet. While these "answer sheet percentiles" are only a point or two lower than the corresponding "booklet percentiles" it is highly probable that this close agreement is due to the superior ability of the students from these twelve colleges, as on several other tests it has been found that the use of separate answer sheets on a test involving the time factor handicaps the average student by as much as from five to ten percentile points. In a study[2] of two carefully matched sections, one using the separate answer sheets, the other the booklet method, it was found that, on the 1938 Coöperative Chemistry Test, the difference in the means of the raw scores amounted to a difference of about 10 in the percentile ranking, that is, students using separate answer sheets would have ranked about ten points higher on the percentile scale if they had taken the same test and placed the answers directly in the test booklet. Unfortunately, no such data are available for this year's test; it is hoped that in future years the comparative scores of matched sections will be available for making the proper correction for the use of the separate answer sheets. It may be noted that while the use of separate answer sheets may involve a change in the *national* percentile ranking, it will make no appreciable change

TABLE 3

CONDENSED PERCENTILES FOR COLLEGES USING SEPARATE ANSWER SHEETS

	Part I	*Part II*	*Part III*	*Total*	
No. cases	1532	1532	1532	1532	
No. colleges	12	12	12	12	
Percentile					Percentile
100	61	57	42	152	100
98	51	46	35	121	98
93	44	39	30	104	93
90	42	35	28	97	90
84	38	31	25	88	84
80	37	28	23	83	80
75	35	27	22	78	75
70	32	25	20	73	70
60	29	20	18	66	60
50	26	17	16	60	50
40	23	14	14	53	40
30	21	11	12	48	30
25	20	9	11	44	25
20	18	8	10	41	20
16	17	6	9	38	16
10	15	4	7	33	10
7	13	3	5	30	7
2	9	0	2	20	2
0	1	0	0	8	0

[2] MARTIN AND ALLEN, "The 'clerical facility' factor for students taking objectively scored tests by direct answer on the test sheet versus separate answer sheets," J. CHEM. EDUC., 17, 75-6 (1940).

TABLE 4

DISTRIBUTION OF COLLEGE AVERAGES
(Total Raw Scores)

	Part I		Part II		Part III			Total	
Raw Score	Booklet	Answer Sheet	Booklet	Answer Sheet	Booklet	Answer Sheet	Raw Score	Booklet	Answer Sheet
46–46.99	1						110–111.99	1	
45–45.99	0								
44–44.99	1						108–109.99	0	
43–43.99	1						106–107.99	0	
42–42.99	1						104–105.99	0	
41–41.99	2						102–103.99	1	
40–40.99	1						100–101.99	0	
39–39.99	3						98– 99.99	1	
38–38.99	5						96– 97.99	0	
37–37.99	4						94– 95.99	1	
36–36.99	4						92– 93.99	1	
35–35.99	1		2				90– 91.99	1	
34–34.99	5		0				88– 89.99	2	
33–33.99	11	1	0				86– 87.99	3	
32–32.99	4	0	0				84– 85.99	3	
31–31.99	11	1	1				82– 83.99	2	
30–30.99	11	3	0				80– 81.99	0	
29–29.99	16	0	2		1		78– 79.99	6	
28–28.99	11	4	1		0		76– 77.99	5	1
27–27.99	10	1	2		0		74– 75.99	6	1
26–26.99	9	2	5	1	1		72– 73.99	6	0
25–25.99	11	1	1	0	3		70– 71.99	7	1
24–24.99	8	0	4	0	1		68– 69.99	6	1
23–23.99	6	0	3	1	1		66– 67.99	7	0
22–22.99	7	1	6	0	4		64– 65.99	10	1
21–21.99	4		4	1	9		62– 63.99	10	2
20–20.99	2		13	2	2		60– 61.99	10	2
19–19.99	1		17	1	17	3	58– 59.99	5	2
18–18.99	1		14	1	12	0	56– 57.99	13	1
17–17.99	0		8	0	17	1	54– 55.99	7	1
16–16.99	0		11	3	9	3	52– 53.99	7	0
15–15.99	2		9	1	18	3	50– 51.99	7	1
14–14.99	1		11	2	13	2	48– 49.99	7	
13–13.99			7	0	14	2	46– 47.99	7	
12–12.99			8	0	9		44– 45.99	5	
11–11.99			8	0	14		42– 43.99	4	
10–10.99			8	1	4		40– 41.99	0	
9– 9.99			6		1		38– 39.99	0	
8– 8.99			1		5		36– 37.99	1	
7– 7.99			2				34– 35.99	1	
6– 6.99			0				32– 33.99	2	
5– 5.99			1				30– 31.99		
Total	155	14	155	14	155	14	Total	155	14

TABLE 5

CONDENSED PERCENTILE CORRESPONDING TO TOTAL RAW SCORES FOR VARIOUS SPECIAL GROUPS

	Sex Difference		Effect of High-School Chemistry		Type of College							
	All Men	All Women	High-School Chemistry	No High-School Chemistry	Men's Liberal Arts	Women's Liberal Arts	Coeducational Liberal Arts	Teachers College	Agricultural and Technical College	Engineering	Junior College	
No. cases	6182	2523	5894	2602	1437	1033	3381	351	341	724	1438	
Percentile												Percentile
100	160	153	160	150	160	141	158	144	144	160	152	100
98	133	113	133	111	134	108	130	110	106	138	126	98
93	115	94	116	91	114	90	112	90	90	126	109	93
90	109	87	110	84	107	85	106	85	82	119	104	90
84	99	78	100	76	97	78	96	75	74	111	94	84
80	94	73	95	71	92	73	91	71	70	106	89	80
75	88	68	90	66	86	68	84	68	66	102	81	75
70	83	64	84	62	82	64	80	63	62	97	76	70
60	74	56	75	54	73	57	70	56	56	87	67	60
50	66	50	67	48	66	50	63	51	49	78	59	50
40	59	44	60	42	58	45	56	44	44	70	52	40
30	51	39	52	37	50	40	49	39	39	62	45	30
25	47	36	49	35	47	37	45	34	37	57	42	25
20	43	33	45	32	43	34	41	32	35	52	38	20
16	40	30	42	29	40	31	38	29	32	48	35	16
10	35	26	36	24	34	27	33	23	27	41	30	10
7	31	23	33	22	31	24	29	20	25	39	26	7
2	21	16	24	14	21	18	19	12	16	29	19	2
0	4	2	3	2	4	11	2	7	11	17	7	0

in the *relative* standing of students in a given class, as the good students will still demonstrate their superiority, no matter what method is used to record their answers.

Table 4 and Figure 1 show that the wide variability of achievement, both for colleges as well as individuals, noted in previous reports[3,4] is also true for the 1939 test.

[3] PHELAN, "The 1936–1937 College Chemistry Testing Program," J. CHEM. EDUC., **14**, 586–90 (1937).

[4] REED, "The 1937–1938 College Chemistry Testing Program," *ibid.*, **16**, 184–90 (1939).

As might be expected, the variability for each part, as well as for the total score, is greater for the individual students than for the colleges, that is, while the scores for the students in a given college may show a wide range in percentile ranking, the mean score for the college may differ but little from that of another college.

TABLE 6

A COMPARISON OF TEST SCORES MADE BY DIFFERENT CHEMISTRY CLASSES IN THE SAME UNIVERSITY

	Three Credit Course			*Four Credit Course for Engineers*	*Advanced Four Credit Course for Superior Students*
	Agriculture	*Science*	*Home Economics*		
Mean raw score, Part I	23.3	22.3	19	37.7	49.6
Percentile Ranking, Part I	31	28	20	74	95
Mean raw score, Part II	15.6	15.5	13.4	30.6	43.7
Percentile Ranking, Part II	48	47	41	83	96.5
Mean raw score, Part III	11.5	11.9	11.3	21.4	29.6
Percentile Ranking, Part III	31	32	31	72	92
Mean total	50.4	49.7	43.8	89.7	122.9
Percentile Ranking, Total	36	35	26	80.5	96.5

In spite of this leveling influence, colleges do exhibit some variation, as may be seen from Figure 1, where the crosses indicating the highest and lowest college averages on each part of the test as well as on the total score are rather widely separated.

Table 5, along with Figures 2, 3, 4, 5, and 6, shows the effect of various factors upon the scores made on this examination. Apparently the typical high-ranking chemistry student, as measured by high achievement on the 1939 Coöperative Chemistry Test is a male prodigy, about sixteen years old, who is attending an engineering school. He has had chemistry in high school and is taking a five-credit chemistry course in college, with five hours of laboratory work and four hours of lecture and recitation work a week. He plans to go into college teaching with engineering as a second choice.

While this paragon may exist, most chemistry students cannot hope to equal his attainments. Proper provisions must, therefore, be made for education suitable to their aptitude and proficiency and suitable allowance be made for differences in training, professional goal, and other influential factors. When students of all degrees of ability are herded indiscriminately into one rigid chemistry course, regardless of the rôle or importance of chemistry in their professional training, it is certain that many good students will be handicapped by the slow pace necessary for the less gifted students in the class. Conversely, the poor students will be discouraged because the standards for passing may be far above their capabilities. The recognition of the rights of the superior student has been acknowledged in many colleges by the establishment of special classes for those students.[5] In one state university three different freshman courses are offered to suit the special requirements of the two thousand or more freshman taking General Chemistry. Students entering the schools of Agriculture, Home Economics, or Science are assigned to a three credit course in descriptive chemistry suited to their needs and abilities, the engineering students are assigned to a four credit course in which special emphasis is laid upon the more exact and scientific aspects of chemistry, while superior students intending to specialize in chemistry or chemical engineering may elect a still more advanced course. In such cases the Coöperative Chemistry Test is of great value in comparing the standards of achievement in the various courses. As it would obviously be unfair to compare these sections with one another, they must be compared with similar sections in other institutions made up of students having the same professional goal. Table 6 gives the results of a comparison of this sort carried out with students in the three different courses mentioned above. The distribution range of each section is shown by the bar graphs in Figure 7. By comparing the results for the various sections with the college averages shown in Figure 1 and with the norms for the various professional groups as drawn in Figure 3 it may be seen that the "advanced" section profited by the special training, making a mean raw score higher than the mean score of the highest college, the engineering section is distinctly above the average, ranking above the "college teaching" group in the pro-

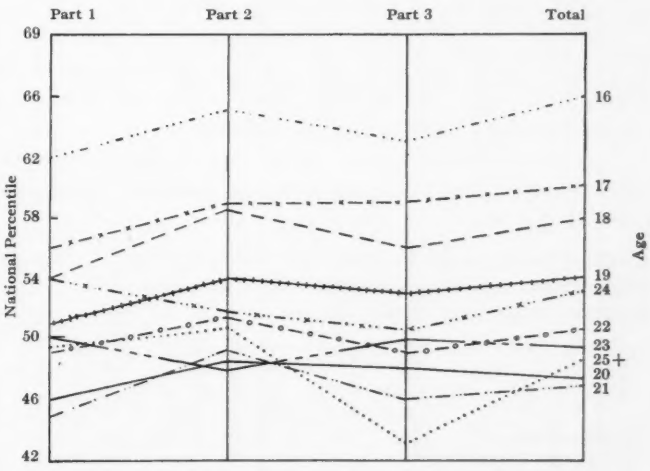

FIGURE 2.—RELATION BETWEEN AGE AND SCORES ON TEST

[5] FERNELIUS, QUILL, AND EVANS, "Experiences in teaching proficiency students," *J. Chem. Educ.*, **14**, 427–33 (1937).

fessional standings, while the students in the three credit course are somewhat below the average for agricultural and home economics students, except in Part II. Occasionally the administrative officers of a university try to cut expenses by eliminating special sections, the segregation of pupils with different professional goals, and other devices which make for more effective and vitalizing teaching. When the results of a nation-wide test such as this are available, the possible effects of including all the students in "one big section" can be more readily visualized. It is apparent, for example, what an injustice would be done to both groups if the engineering students were to be given the same chemistry course as the students from the School of Home Economics.

Aside from the use of the test in evaluating the performance of various classes within a given School in terms of national norms, the Coöperative Chemistry Test has been found to be useful for the various purposes enumerated by Professor Reed.

(1) Recognition of superior students.

(2) Advising students with regard to their future line of work.

(3) Evaluation or acceptance of chemistry credits from other institutions.

It is hoped that each year will see more and more college chemistry teachers coöperating in this project

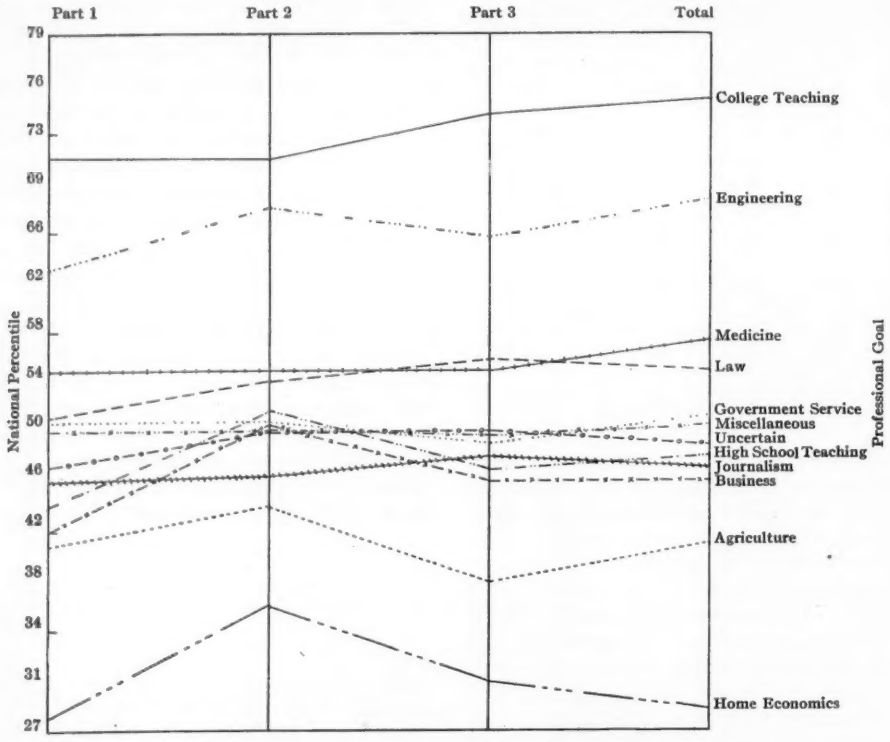

FIGURE 3.—RELATION BETWEEN PROFESSIONAL GOAL AND SCORES ON TEST

TABLE 7

CORRELATIONS

	A. C. E.	Part I	Part II	Part III	Total	N
Independent estimates	0.43[a]	0.70	0.58	0.58	0.80	1849
American Council on Education, Psychological Examination		0.45	0.40	0.47	0.51	2407
Part I			0.59	0.64	0.88	2407
Part II				0.55	0.86	2407
Part III					0.82	2407

[a] N = 736 for this coefficient.

TABLE 8

COÖPERATIVE CHEMISTRY TEST IN QUALITATIVE ANALYSIS—PROVISIONAL PERCENTILES

Based on the scores of 887 students in 29 colleges

Percentile	*Score* (Maximum Score 93)
100	90
98	68
93	60
90	55
84	49
80	46
75	44
70	41
60	34
50	30
40	26
30	21
25	19
20	16
16	13
10	8
7	6
2	1

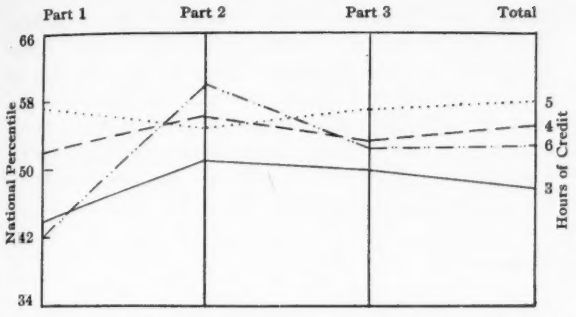

FIGURE 4.—RELATION BETWEEN NUMBER OF CREDIT-HOURS AND SCORES ON TEST

by offering suggestions for the improvement of the test, giving the test to their students, and sending in the results to the Coöperative Test Service.

CORRELATION STUDIES

In order to study the relation between a pupil's score on the Coöperative Chemistry Test and the teacher's estimate of the student's ability, the coefficient of correlation was worked out for the 1849 students for whom their instructors sent in an independent estimate of chemical ability. Apparently many instructors continue to base their estimate of chemical ability upon their students' mastery of descriptive material such as the items included in Part I, "Information and Vocabulary" in the Coöperative Test, as the correlation is distinctly higher for this part than for the other two parts of the test. The over-all correlation coefficient was 0.80, showing that, as a whole, the results of the test did not surprise the instructors of these 1849 students. Table 7 summarizes these and other correlations.

An interesting correlation is that between the scores on the various parts of this chemistry test and the scores made by the 2407 students for whom the scores on the Psychological Examination of the American Council on Education were also available. Evidently these two tests do not require or measure quite the same abilities, possibly some of the more brilliant students who made high scores on the psychology examination were repelled by the large amount of memory work required for the mastery of the usual course in general chemistry. Chemistry teachers who wish to keep such pupils interested in science must provide opportunities for original thinking and experimentation if they wish to avoid boring these bright students with long encyclopedic dissertations involving only the familiar "occurrence, preparation, properties, and uses" of the various elements and compounds.

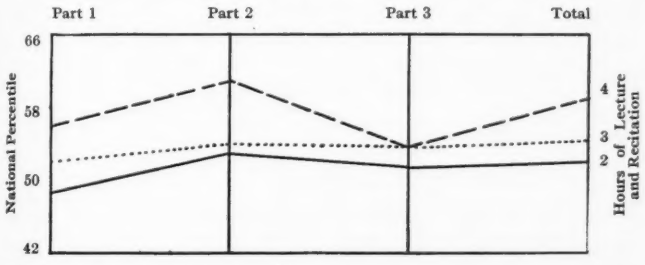

FIGURE 5.—RELATION BETWEEN NUMBER OF HOURS OF LECTURE AND RECITATION AND SCORE ON TEST

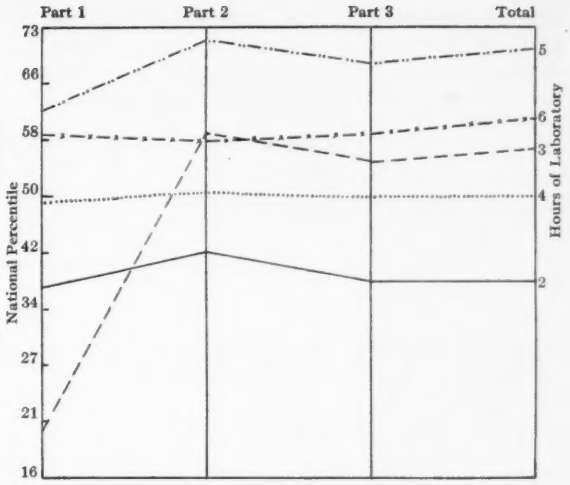

FIGURE 6.—RELATION BETWEEN NUMBER OF HOURS OF LABORATORY WORK AND SCORES ON TEST

The intercorrelation between the three parts of the examination and the total score is better, on the whole, than was the case last year. Part II is now in better agreement with Part I, Part III, and the total score than was the case last year, the respective correlations being 0.499, 0.505, and 0.776 for the 1938 test and 0.59, 0.55, and 0.86 for the 1939 test. Tests for

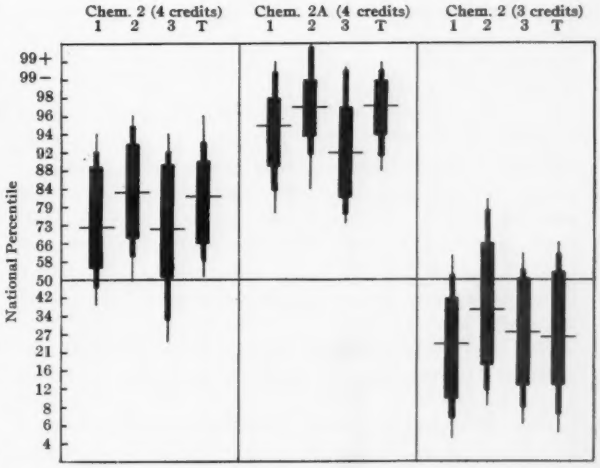

FIGURE 7.—DISTRIBUTION OF TEST SCORES FOR DIFFERENT SECTIONS IN A STATE UNIVERSITY. (SEE FIGURE 1 FOR EXPLANATION OF BAR GRAPHS)

internal consistency indicate that the correlations between the independent estimates, A. C. E. Psychological Scores, scores on the parts of the chemistry test, and the total scores on the chemistry test are comparable.

THE COÖPERATIVE CHEMISTRY TEST IN QUALITATIVE ANALYSIS

Lack of time precluded a more thorough study of the Coöperative Chemistry Test in Qualitative Analysis. Table 8 gives the provisional percentiles, based upon the scores of eight hundred eighty-seven students in twenty-nine colleges. Altogether, sixty-seven colleges used this test, but only thirty-two of these institutions sent in their scores in time to be included in this report. The Test Committee will welcome any comments or suggestions from the users of this test.

The "CLERICAL FACILITY" FACTOR *for* STUDENTS TAKING OBJECTIVELY SCORED TESTS *by* DIRECT ANSWER *on the* TEST SHEET *versus* SEPARATE ANSWER SHEETS[1]

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THE growing use of the Coöperative Chemistry Examination is evidence of the increasing interest which chemistry teachers are taking in this national project. In 1938 the use of separate answer sheets was introduced for two reasons: first, the schools using either hand or machine grading would save money by letting one set of questions serve for several different divisions meeting at different times; second, schools equipped with the International Test Scoring Machine would use the machine to grade the chemistry examinations.

As long as each school uses only one method for recording the answers, that is, either placing answers directly in the question book or on the separate answer sheet, it is probable that the *relative* standing of the students would not be seriously affected. When, however, comparisons are to be made between different schools, means must be found to correct the raw scores for schools using separate answer sheets, for these tests are given upon a time basis and more time is needed to record these answers on a second sheet in the proper place than is necessary to place the answers directly in the spaces provided with each question in the question book. The skill necessary to use the separate answer sheets is a form of "clerical facility," hence, uncorrected scores made on the Coöperative Chemistry Test, using separate answer sheets, measure this clerical ability as well as chemical ability. The instructions issued with the 1938 chemistry test state that "a particular raw score is usually evidence of a higher scaled score when the test is given with answer sheets than when the test is given the usual way."[2] To determine exactly how much the use of separate answer books would affect the percentile standing of a given class on the Coöperative Chemistry Test it was thought advisable to make a careful study of the question, using two carefully matched sections for comparison. The findings, although strictly applicable only to the 1938 form of the test, should also be approximately true for all future editions of the Coöperative Chemistry Test which involve the same number and types of responses as the 1938 edition.

The procedure used was to give the Coöperative Chemistry Test to two carefully matched sections, Section 1 using the separate answer sheets, Section 2 using the "answer in book" method. The sections were matched upon the basis of the grades received the previous semester in general chemistry. These semester grades, in turn, were based upon the weighted mean of three factors, the average of tests and examinations

[1] Presented before the Division of Chemical Education at the ninety-sixth meeting of the A. C. S., Milwaukee, Wis., September 7, 1938.

[2] Form C, Directions for Administering and Scoring the Cooperative Tests, 1938 Edition, Coöperative Test Service, New York City.

TABLE 1

A COMPARISON OF THE STANDING OF MATCHED SECTIONS ON THE 1938 COÖPERATIVE CHEMISTRY TEST, SECTION 1 USING SEPARATE ANSWER SHEETS, SECTION 2 USING "ANSWER IN BOOK" METHOD

Grade Level	Grade A or H (Superior) Section 1	Grade A or H (Superior) Section 2	Grade B (Average) Section 1	Grade B (Average) Section 2	Grade P or C (Below Average) Section 1	Grade P or C (Below Average) Section 2	Totals Section 1	Totals Section 2
(1) Number of students	50	52	47	44	40	41	137	137
(2) Mean raw score	92.3	105.3	76.8	88.8	63.5	71.6	78.6	89.9
(3) Standard deviation	23.6	19.13	17.72	18.08	21.07	24.86	23.96	24.92
(4) Standard error of the mean	3.34	2.65	2.58	2.73	3.33	3.88	2.05	2.13
(5) Percentile ranking	73.6	83.5	57.8	70.7	41.9	52.0	59.6	71.6
(6) Difference between means	13.0		12.0		8.1		11.3	
(7) Standard error, difference between means	4.27		3.76		5.1		2.96	
(8) Significance ratio = (6)/(7)	3.05		3.19		1.59		3.83	
(9) Percentile difference in national ranking, (Section 2) − (Section 1)	9.9		12.9		10.1		12.0	

counting sixty per cent., the final examination (of the objective type) counting thirty per cent., the remaining ten per cent. being the class instructor's estimate of the student's performance.

Table 1 gives the semester grade distribution for these sections and the results of the statistical study of the grades on the Coöperative Chemistry Test. All students had had previous training in the use of separate answer sheets in another course (mechanical drawing) and the time allotment was the same for both sections, hence the difference should be an accurate measurement of the importance of the "Clerical Facility Factor" for this test.

It will be noted that at every grade level there is a difference of from ten to twelve percentile points in favor of the students using the "answer in book" method. There is less than one chance in a thousand that the difference of the means, 11.3, is due to a chance variation between the sections, even supposing that the sections had not been matched. The fact that the sections were matched would make this difference even more significant from a statistical standpoint because the "standard error of the difference between a pair of related samples would be smaller than for a pair of independent samples."[3]

[3] LINDQUIST, "A first course in statistics," Houghton-Mifflin Company, Boston, Mass., **1938**, p. 125.

In view of these results it would appear that the use of the separate answer sheets in place of the use of the spaces provided for answers in the booklets may handicap students ranking near the national median by ten percentile points. This handicap is about the same for students near the 80 percentile mark and is somewhat greater for those in between. An independent check made on a section of advanced students ranking in the upper 5 percentile group showed that the percentile difference at this level amounted to only one percentile point, although the actual difference of the means, 5.1, approaches that of the lower group in this study. Apparently, the extremely good students are not bothered quite so much by the use of separate answer sheets as the average students, while the poor students have so much trouble in selecting the correct answers that an additional hazard does not lower their scores very much more.

ACKNOWLEDGMENT

The authors are indebted to H. H. Remmers for suggestions relating to presentation of the data and to Miss Elizabeth Brant and L. E. Thomas for help with the grading machine and with the calculations and tabulations of results.

COSMETICS—*a* FERTILE FIELD *for* CHEMICAL RESEARCH[1]

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THE passing of the new Federal Pure Food, Drug and Cosmetic Act of 1938—the long-fought Copeland Bill—and the commendable efforts both to formulate and to comply with the regulations for the prosecution of this law, have revealed a remarkable lack of reliable scientific data on the products and treatments that constitute the basis of the vast cosmetic industry.

According to the new law (*1*)

The term "cosmetic" means (1) articles intended to be rubbed poured, sprinkled or sprayed on, introduced into, or otherwise applied to the human body or any part thereof for cleansing, beautifying, promoting attractiveness, or altering the appear-

[1] Presented by title before the Division of Chemical Education at the ninety-eighth meeting of the A. C. S., Boston, Mass., September 14, 1939.

ance, and (2) articles intended for use as a component of any such articles; except that such term shall not include soap.

The exemption of soaps was allowed, allegedly, to prevent their being taxed as a luxury. But since soaps are so widely advertised as popular stand-bys and sure guides to beauty, health, and happiness, both soaps and perfumes, for the purposes of this paper, will be considered as allied industries.

In another paper presented before this Division (*2*), it was prophesied that the inevitable passing of a law to control cosmetics would generate a spontaneous demand for chemists that understand these former mysteries. That time has now come and the demand is upon us. This does not mean that there are so many positions yawning open in the commercial and industrial branches of the work (for the depression is still with us, and staffs are still curtailed), but that there is a basic need for information at the source, and for research workers who can undertake to supply it.

To aid in the prosecution of the many necessary checks required by the Food and Drug Administration, whole tables of reliable qualitative and quantitative tests are required. Since the new law covers adulteration and misbranding, many additional tests must be available for undesirable or forbidden substances which might be incorporated into otherwise simple products.

One of the first major problems confronting the Administration is that of certified colors for cosmetics. Instead of the comparatively simple task presented by the relatively few colors used in foods, the list requested for certification for use in the wide variety of cosmetic products numbered over two hundred.[2] Many of these colors have been used for years, presumably safely and successfully, with no need for, nor thought given to, testing of any kind. This is especially true of many imported colors. Now that certification is required, identification must be assured, and tests must be available both for individual colors and for selective identification of the ingredients of mixtures. A full range will include standard colors, intermediates, and isomers.

The tests for colors used in cosmetics may be physical as well as chemical. The devising of a range of spectroscopic tests may appeal to some research workers. Because of the small quantities involved in many cases, the range of micro-tests should be enlarged considerably.

The dyes used in hair colorings are not included in the lists for certification, because special regulations have been made for them. Because of the problems of personal idiosyncrasy or sensitivity to the amino-dyes, preliminary tests, to be made on the individual, are exacted. However, in cases of positive reaction from this preliminary test, it would be valuable to know which ingredient of the preparation (usually a mixture) is the actual offender.

Tests analogous to those required, which could serve as patterns for further research, are those devised by Griebel (*3*), Cox (*3a*), and Pedretti (*4*). Tests for these individual amino-dyes in the presence of one another are essential because so many of the finished products are now rather complicated mixtures.

There is considerable confusion about other preparations through the loose use of such terms as "hair tonic," "hair restorer," "hair rejuvenator," and so forth. Because some of these may actually be hair dyes, simple tests must be available for both the metallic salts commonly used (*5*, *6*), and for resorcin, beta-naphthol, pyrogallol, pilocarpin, and other organic compounds.[3]

The ingredients of creams and lotions for the skin present few difficulties in their basic ingredients. Simple tests, specific if possible, should be available for the preservatives which may be used; and for anti-oxidants. Of the latter, over twenty substances are now in common use, many of them complicated organic compounds, sold principally under proprietary trade names.

In case of untoward results from the use of a cosmetic product, the investigator should be able to determine whether the trouble is due to some primary irritant (such as alkalies, formaldehyde, phenol, mercury compounds, and so forth); or to some allergenic substance (such as almond oil, or some natural or synthetic ingredient of the perfume used). Oil of bergamot and methyl heptine carbonate have been known to cause trouble, and other aromatic substances may be suspect. Here again, micro-tests are required because of the extremely small quantities occasionally involved.

The extremely rare case of irritation from face powder is now usually traceable to the perfume, rather than to the lead compounds or orris root, which always figure in the lists copied freely from book to book.[4]

Sun-tan preparations present a whole set of problems in themselves. Vehicles, sensitizers, and screens or filters for light should be readily ascertainable.

The limited number of substances available for use in deodorants, anti-perspirants, and depilatories, makes qualitative testing comparatively simple. This question may become an academic one, because these preparations, in addition to "altering the appearance and promoting the attractiveness" of the person, also "affect some function (perspiration) or structure (hair) of the body." The latter characteristics remove them from the class of cosmetics into drugs, for which publication of active ingredients is required.

From the foregoing résumé, it can be seen that on the analytical side, research is needed for information on practically everything used in every type of cosmetic product in common use. The departments of chemistry in colleges and universities can well add projects on cosmetics to those on foods and drugs, and direct the

[2] The complete lists of certified colors for all classes of controlled products should be obtained from the Food and Drug Administration, Department of Agriculture, Washington, D. C.

[3] See Bibliography for books giving typical recipes.

[4] Arrowroot starch is another substance alleged to be a cause of trouble in face powders. The author recalls an elaborate recipe for a powder given to a patient by a physician who told her she was allergic to arrowroot and should never use a powder containing it. When the questions were relayed back as to how many face powders he had examined recently, and in which ones he had found arrowroot starch, he chose to consider the incident closed.

thoughts of those with the right chemical background and aptitude to some of the many and various kinds of work that need to be done.

Just as much, if not more, awaits the qualified investigators in other phases of research on cosmetics. The rapidly increasing movement for instruction on good grooming, as an integral factor in personal hygiene and the development of personality, offers to teachers of chemistry on all educational levels fine opportunities for research and the collection of statistical data on the use and effectiveness of various cosmetic products. Here, chemistry makes a good starting point, but for the effective organization and prosecution of such tests, the instructor needs a good supplementary knowledge of living human skin and hair, from both the scientific standpoint of cosmetic dermatology and the esthetic—types of complexion, suitability of colorings, and so forth.

Knowledge of this kind cannot be learned from books. Once the basic scientific principles are assimilated, the practical knowledge can be acquired only through actual clinical work with classes of students. Several more or less successful programs are now under way in various colleges and high schools, associated with some diluted chemistry of cosmetics and the compounding of preparations. This is all very well, but three years of classes in what is called "Cosmetic Hygiene" at New York University, have shown the author that most students are far more interested in what types of cosmetics they should use and what the products will do to and for them, than in what is in them or how they are made.

Such courses can be easily fitted into any program from Junior High School up. When worked out in coöperation with teachers of home economics, physical education, and health, they can serve as splendid media for sound consumer education on cosmetics. After the long siege of destructive terrorizing to which the trade and industry as a whole were subjected by the self-appointed "apostles to the guinea pigs" and other professional reformers, correct information, given out under legitimate educational auspices, is usually most welcome (*7*).

In addition to this type of research directly with the users of cosmetics, there are many more advanced problems, the solving of which will help to establish needed basic principles related to the composition and effects of cosmetic preparations and treatments. Among these, the following could well offer serious study to research workers in biochemistry, especially in institutions with clinical facilities in cosmetic dermatology:

(1) *The Phenomena of Absorption by the Skin.*—Granted that we still preach that "the skin is fed only by the blood stream," it would be desirable to have proof, free of mere authoritarian dicta, of the possibility or impossibility of improving the skin by the local, external application of appropriate cosmetic products. Comparative data on the penetration and absorption of various substances would help to dissipate extravagant claims for cosmetic products.

(2) *The Relationship, if Any, between Systemic Conditions (Acidosis, Pregnancy, Menstruation, and so Forth) and the Success or Failure of Cosmetic Treatments.*—Reliable data on this would doubtless explode the popular theories about "acid in the blood" as the prize excuse when anything goes wrong.

(3) *The Identification of, and Collecting of Statistical Data on, Idiosyncrasies and Tolerances for Substances Used in Cosmetics.*—This could easily be done in institutions where an associated hospital conducts clinics for allergy and conditions of the skin. Notable work of this kind has been done by Harry L. Baer, M.D. (*8*), at the Skin and Cancer Foundation, in Pittsburgh.

(4) *The Actual Facts about the Use of Vitamins, Hormones, and Other Organotherapeutic Substances for Cosmetic Effect.*—These would settle the claims for such border-line products; and possibly prove the contention of Goodman (*9*), that when and if any improvement does take place, the substance is out of cosmetics and into drugs and medicines.

(5) *The Development of Safe and Suitable Hair Colorings.*—The need here is to find substitutes for the allergenic substances, which are now the most commonly used, and the most satisfactory dyes to use.

(6) *The Practical Application of the Work of Astbury, Speakman, Woods, and Others (10) to Problems in the Permanent Waving of Hair.*—This study, on the molecular structure of keratin in hair, is currently being tested out for practical application in England. In America, while many writers and rewriters have seized on the idea and worried it, no one seems to have done anything particularly constructive about it.

The solution of any phase of these suggested problems could well furnish the material for a thesis, and make a good step toward opening up this field—so closely related to the field of cutaneous medicine—to the recognition and consideration which have been too long denied to it by scientific and professional people.

On the more utilitarian side, there are studies to be made on the effects of various containers on cosmetic products, and vice versa. Glass, carton, metal foils, and plastics—all these present problems which might well be taken up by independent investigators, and even turned to profit. The application of new raw materials should never be made without controlled tests—preferably clinical—both with the raw materials themselves and with the finished cosmetic products before they are marketed.

Research on several of these problems, by some of the better manufacturers, has been continuous and prolific of many good ideas for the improvement of their products, but practically all the records of this valuable work remain rightfully in the private archives of whoever financed them. There they will remain, at the cost of considerable overlapping and duplication of effort, until such problems are undertaken openly in the university laboratories and clinics, whence the findings

stand a better chance of acceptance and publication by the reputable scientific periodicals.

Even in days of unfavorable economic conditions, there is a fairly steady demand for chemists with a sound knowledge of cosmetic preparations and treatments. Anyone that hopes to accomplish anything, however, must realize that study of these products cannot be dissociated from their practical application in beauty culture. The would-be investigator should supplement his knowledge of chemistry with pertinent information from anatomy, physiology, dermatology, physics, and physical therapy.

All phases of work in cosmetics should make a strong appeal to women chemists. It is obviously a woman's business, yet relatively few women scientists have given it serious consideration (*11*). Teachers of chemistry, particularly teachers in secondary schools, should investigate the possibilities of teaching related science in the vocational and industrial schools where cosmetology (*12*) (officially accepted term for professional beauty culture) is taught as a trade course for girls. Boards of education are learning that the prospects of success are better from the trained scientist who picks up the cosmetology, than from even the best so-called practical person who tries to build up a background of science. Chemistry has frequently served as the wedge into a good position, but the importance of it in the actual study of cosmetology has been greatly exaggerated. Other branches of science, as enumerated above, are more pertinent and more valuable (*13*). In addition, the instructor must have a fair practical knowledge of, even if she has not actual technical skill in, current procedures in beauty culture. Above all, she must be willing to practice what she preaches, and try to look like a good example of the possibilities of the business.

So "research in cosmetics" means far more than the confecting of a ravishing lipstick, or the creating of some magical cream or lotion, guaranteed to restore lost youth and beauty. In the opinion of this investigator, the multiplication of courses which teach the compounding of cosmetics is rather to be deplored. If classes could be limited to the manufacturers, who ought to keep up with the latest and best, they might be justified; but, open to anybody and everybody, they simply help to flood the market with "kitchen-made" products, which compete unfairly with those of the legitimate manufacturers.

There are already too many persons who know merely how to make cosmetics, but too few engaged in the scientific studies on which the future of this vast and valuable industry should rightfully be laid; and not nearly enough in the interpretation of cosmetic arts and practices, or in the education of prospective consumers on the scientific choice and artistic use of them.

A good knowledge of the right kind of chemistry offers a fine introduction to this whole field. The organizing of the necessary scientific knowledge, and the application of it to the various problems waiting to be solved should offer alluring prospects to those that are properly equipped to do something about them. The horizons are broad and the future most promising for those that are willing to take cosmetics and beauty culture seriously and help to establish these worthy studies on a sound scientific basis.

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HYDROXAMIC ACIDS *in* QUALITATIVE ORGANIC ANALYSIS

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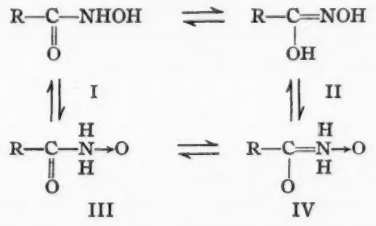
INTRODUCTION

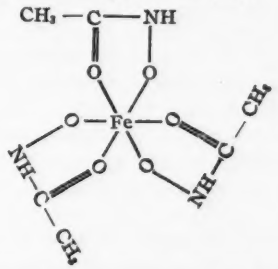
HYDROXAMIC ACIDS may be looked upon as *N*-hydroxy-derivatives of the acid amides (I) or as oximes of the carboxylic acids (II), each of which may also be represented by an amine oxide formula (III, IV). These tautomeric substances are



most commonly prepared by the interaction of hydroxylamine with acid derivatives such as the esters, (*1*, *2*, *3*, *4*) chlorides, (*5*, *6*) and anhydrides (*7*). For example, just as water causes the *hydrolysis* of ethyl benzoate to ethyl alcohol and benzoic acid, and as ammonia brings about its *ammonolysis* to ethyl alcohol and benzamide, so hydroxylamine reacts with this ester to form ethyl alcohol and benzhydroxamic acid (*hydroxylaminolysis*).

$$C_6H_5COOC_2H_5 + H_2O \longrightarrow C_6H_5COOH + C_2H_5OH$$
$$C_6H_5COOC_2H_5 + NH_3 \longrightarrow C_6H_5CONH_2 + C_2H_5OH$$
$$C_6H_5COOC_2H_5 + NH_2OH \longrightarrow C_6H_5CONHOH + C_2H_5OH$$

Hydroxamic acids are distinguished by the formation of insoluble, green copper salts but more particularly by the production of soluble, red to violet-colored ferric salts such as that from acethydroxamic acid, $Fe(CH_3CONHO)$. This Hantzsch (*8*) found to be a poor conductor of electricity in aqueous solution. In the absence of knowledge of the molecular magnitude of the complex ion present, two formulas may be suggested. The one offered by Hurd (*9*) assumes a double formula and relates the complex to the ferricyanide type: $Fe[Fe(CH_3CONHO)_6]$. The other possibility is the internal complex (chelate) derived from the monomeric formula by Werner (*10*):



The second structure is supported by Hantzsch's observation that ferric acethydroxamate gives no precipitate with ferrocyanide and reacts with ammonia only after several hours. In fact, the relatively great stability of the ferric hydroxamates (toward hydrochloric acid and ammonia) makes it possible to distinguish these from the similarly colored enolates and phenolates and thus to detect hydroxamic acid groups in the presence of phenolic groups.

Since esters and other acid derivatives are readily hydroxylaminolyzed and since even a partial conversion is easily detected by means of ferric chloride, this reaction serves as an excellent qualitative test for esters—an application recently introduced by Feigl (*11*, *12*). Feigl's emphasis on microtechnic appears to have retarded the general adoption of this test. At Brooklyn College, a modification of Feigl's procedure has been highly successful in the hands of students. Since the test can be carried out in a fraction of a minute as compared with the lengthy hydrolysis test commonly recommended, it has greatly simplified the analysis of the indifferent oxygen compounds (Kamm's group V) (*13*). All such substances are tested for the carbonyl group (phenylhydrazine), the hydroxyl group (phosphorus pentachloride, thionyl chloride, or acetyl chloride), and the ester group (hydroxylamine). Saponification tests then need only be run when the

hydroxamic acid test is positive. The avoidance of unnecessary saponification tests allows the detection of alcohols and ethers to be made quickly.

Since hydroxamic acids may be prepared in manifold ways and are so readily detected it appeared to be profitable to explore their use in the whole field of qualitative organic analysis. The following systematic survey includes some well-known tests, several recent innovations of Feigl (*12*), as well as a few original applications not previously published. It comprises practical tests for alcohols, ethers, aldehydes, esters, lactones, acid chlorides, anhydrides, phenols, oximes, carboxylic acids, sulfonic acids, nitro compounds, and amides.

ALCOHOLS

Phosphorus pentachloride (for liquids) and thionyl chloride (for solids) are superior to sodium in detecting the hydroxyl group of alcohols. There is less interference from enolizable compounds (particularly ketones), while tertiary alcohols, which react very sluggishly with sodium, react vigorously with these halides. Like sodium, however, both of these reagents react violently with water which, therefore, interferes with the test, except in the case of water-soluble alcohols, when a positive test is determined by conversion to a water-insoluble product (chloride). The use of acetyl chloride on water-soluble alcohols likewise depends on a change in solubility (and odor). This reaction may be applied to water-insoluble alcohols as well, if another criterion for ester formation is employed. Here the reaction with hydroxylamine discussed in the introduction comes into play. Since tertiary alcohols are converted to chlorides, rather than to acetates, by acetyl chloride alone, dimethylaniline is employed conjointly. The reactions involved in the test are

$$ROH + CH_3COCl + C_6H_5N(CH_3)_2 \longrightarrow ROCOCH_3 + C_6H_5N(CH_3)_2\cdot HCl$$
$$ROCOCH_3 + NH_2OH \longrightarrow ROH + CH_3CONHOH$$
$$3CH_3CONHOH + FeCl_3 \longrightarrow 3HCl + Fe(CH_3CONHO)_3$$

Since the test depends on the formation of an ester, water does not interfere. This series of reactions thus appears to offer the closest approach to a universal test for alcohols.

Procedure.—Mix 0.5 cc. of acetyl chloride with an equal volume of dimethylaniline. No heat effect is observed. Then add 0.5 cc. (or 0.5 g. in the case of solids) of the alcohol. Heat is evolved (more or less rapidly depending on the class of the alcohol) and concomitantly the mixture separates into two layers. Ice is then added to decompose unchanged acetyl chloride. The test material now consists of an oily ester layer and an aqueous solution of dimethylaniline hydrochloride, acetic acid, and hydrogen chloride. A drop of the ester is removed by means of a pipet and tested with hydroxylamine as described below (see ESTERS).

ALDEHYDES

Angeli (*14*) discovered that aldehydes react with sodium nitrohydroxamate (the salt of $NO_2NHOH \rightleftharpoons HONO—NOH$ prepared by the action of ethyl nitrate on hydroxylamine) to form hydroxamic acids. Later Rimini (*15*) noted a similar reaction with sodium benzenesulfonhydroxamate. A common intermediate in these reactions was postulated by Angeli (*16*) which he termed nitrosyl (HN=O, the prototype of nitroso compounds).

$$NaONO—NONa \longrightarrow NaONO + NaN{=}O$$
$$C_6H_5SO_2NHONa \longrightarrow C_6H_5SO_2Na + NaN{=}O$$
$$NaN{=}O + RCHO \longrightarrow RCONHONa$$

Although this hypothetical intermediate is supported by Piloty's (*17*) study of *N*-alkyl benzenesulfonhydroxamic acids, it has recently been challenged (*18*).

This reaction has been recommended by Angeli (*16*) for distinguishing aldehydes from ketones. Certain exceptions are to be noted, however. *Para*-hydroxyaldehydes and *ortho*-nitrobenzaldehyde[1] do not yield hydroxamic acids, while, on the other hand, benzyl ketones (methyl benzyl ketone, desoxybenzoin) do (*19*). The latter may be explained by the observation of Jenkins (*20*) that benzyl ketones readily undergo autoxidation to yield benzaldehyde.

$$C_6H_5CH_2COR + O_2 \longrightarrow C_6H_5CHO + RCOOH$$

Procedure.—Dissolve a few milligrams of benzenesulfonhydroxamic acid (*17*) in 0.5 cc. of methanol, add a drop or a crystal of aldehyde followed by 0.5 cc. of 2 *N* potassium hydroxide (in methanol). Heat to boiling, cool, acidify with dilute hydrochloric acid, and add a drop of ten per cent. ferric chloride.

ESTERS

The reaction between hydroxylamine and esters has already been discussed. Except with the most reactive esters (oxalates, formates) the presence of alkali is necessary to obtain a practical yield (*3*). Lactones react like esters. Acid chlorides and anhydrides react well under the same conditions but may be distinguished from esters by their ability to be converted (at least partially) by hydroxylamine *hydrochloride*. The only exceptions noted among the esters are the derivatives of carbonic acid (carbonates and carbamates (urethanes)). This is probably due to the instability of the hydroxyureas (*21*).

$$RCOOR' + NH_2OH \longrightarrow RCONHOH + R'OH$$
$$RCOO\text{(}\llcorner\text{)} + NH_2OH \longrightarrow RCONHOH\ (\llcorner OH)$$
$$RCOCl + NH_2OH \longrightarrow RCONHOH + HCl$$
$$(RCO)_2O + NH_2OH \longrightarrow RCONHOH + RCOOH$$

False positive tests are obtained with compounds containing the grouping $CCl_3C(OH)-$ as in chloral hydrate and trichloro-*tert.*-butyl alcohol. Chloroform gives a negative test.

$$CCl_3C(OH)R_2 + NH_2OH + H_2O \longrightarrow R_2C(OH)CONHOH + 3HCl$$

Procedure.—To one drop of an ester add 0.5 cc. of normal hydroxylamine hydrochloride solution (in methanol) and 0.5 cc. of potassium hydroxide solution

[1] *Cf.* Reference 13, p. 258.

(2 *N* in methanol). Potassium chloride precipitates. Heat to boiling and cool, or allow to stand at room temperature for a few minutes. Acidify with dilute hydrochloric acid (0.5 cc. of 2 *N* aqueous solution) and add a drop of ten per cent. ferric chloride.

ETHERS

Ethers give negative results in the tests described above for alcohols and for esters. Since it is known, however, that ethers may be converted to esters by treating with organic acids in the presence of a strong acid (*22*, *23*, *24*), it seemed possible to detect ethers indirectly through esters. This proved feasible.

$$ROR' + 2CH_3COOH \longrightarrow CH_3COOR + CH_3COOR' + H_2O$$

Acetals and alkyl carbonates may also be expected to respond to this test.

Procedure.—Gently reflux a mixture of 0.5 cc. of an ether, 1.0 cc. of glacial acetic acid, and 0.25 cc. of concentrated sulfuric acid for five minutes. Cool and add ice to separate the insoluble product. Test a drop of this for esters as described above.

CARBOXYLIC ACIDS

To test for the carboxyl group, Kamm[2] recommends the conversion of the acid to the amide through the acid chloride. The formation of the neutral amide from the originally acidic substance serves to detect the carboxyl group and to distinguish it from phenolic and sulfonic groups. Since this test requires the separation of the amide it is more convenient to replace the ammonia by hydroxylamine, thus producing the hydroxamic acid which is readily detected in solution by means of ferric chloride even when present in relatively small amounts (*25*).

$$RCOOH + SOCl_2 \longrightarrow RCOCl + SO_2 + HCl$$

Procedure.—Treat 0.05 g. of an acid with 0.5 cc. of thionyl chloride and heat in a water bath (hood) employing a short air condenser. When the excess of thionyl chloride has evaporated, treat the residue as in the test for esters.

Note: Formic acid is readily converted to formhydroxamic acid by heating directly with hydroxylamine (*33b*).[3]

SULFONIC ACIDS

By reversing the Angeli-Rimini test for aldehydes, Feigl (*26*) has developed a useful test for the sulfonic acid group. The sulfonic acid or its salt is converted to the sulfonchloride and then to the sulfonhydroxamic acid. Reaction with acetaldehyde completes the test.

$$RSO_2OH + SOCl_2 \longrightarrow RSO_2Cl + SO_2 + HCl$$
$$RSO_2Cl + NH_2OH \longrightarrow RSO_2NHOH + HCl$$
$$RSO_2NHOH + CH_3CHO \longrightarrow CH_3CONHOH + RSOOH$$

Procedure.—The account of the procedure is given by Feigl and co-authors (*26*).

[2] *Cf.*, Reference 13, p. 152.
[3] *Cf.*, *Ibid.*, 12, p. 295.

PHENOLS

Phenols react with acetyl chloride in the cold, yielding hydrogen chloride and the aryl acetates, but with remarkably little heat effect as compared with the alcohols. Aryl acetates, of course, yield acethydroxamic acid with hydroxylamine. As mentioned earlier, the presence of phenols does not interfere with the detection of hydroxamic acids by ferric ion.

$$ArOH + CH_3COCl \longrightarrow CH_3COOAr + HCl$$

Procedure.—To half a gram of a phenol add one cc. of acetyl chloride. After a minute or two add ice and agitate. Test a drop of the oily layer for esters as described above.

OXIMES

Mulliken's (*27*) only application of hydroxamic acids appears to be a reversal of the ester test given above in which the hydroxylamine produced by the acid hydrolysis of an oxime is detected by its conversion to benzhydroxamic acid by means of benzoyl chloride.

$$R_2C{=}NOH + H_2O \longrightarrow R_2CO + NH_2OH$$

Procedure.—*Cf.*, Reference 27.

Note: Aldoximes may be distinguished from ketoximes by their direct conversion to hydroxamic acids by means of Caro's acid (H_2SO_5) (*28*) or more simply by means of hydrogen peroxide in the presence of ferric chloride (*29*).

NITRO COMPOUNDS

Mulliken[4] recommends the reduction of nitro compounds to alkylhydroxylamines by means of zinc dust in the presence of ammonium chloride. The reduction products are detected by their reducing action on Tollens' reagent. This does not distinguish nitro compounds from azo or azoxy compounds which under the conditions of the test yield hydrazo compounds which also reduce Tollens' reagent. The presence of a reducing group such as aldehyde in the original compound precludes its use. These drawbacks may be avoided by converting the alkylhydroxylamine to an *N*-alkylhydroxamic acid by means of benzoyl chloride. Like their prototypes, *N*-alkylhydroxamic acids yield brilliantly colored complexes with ferric ion (*30*). Nitroso compounds will, of course, respond to the same test.

$$RNO_2 + 2Zn + H_2O \longrightarrow RNHOH + 2ZnO$$
$$RNHOH + C_6H_5COCl \longrightarrow C_6H_5CONROH$$
$$3C_6H_5CONROH + FeCl_3 \longrightarrow Fe(C_6H_5CONRO)_3 + 3HCl$$

Procedure.—Proceed as in Mulliken[4] or Shriner and Fuson (*31*) but instead of testing with Tollens' reagent add a drop of benzoyl chloride, acidify with dilute hydrochloric acid, and add a drop of ten per cent. ferric chloride.

Note: This test applies to aliphatic as well as aromatic nitro compounds. Primary nitroparaffins may

[4] *Cf.*, Reference 27, p. 32.

be distinguished by their isomerization to hydroxamic acids (*32*) or by the benzoylation of the alkali salt followed by hydrolysis of the resulting hydroxamic acid benzoate (*33*).

$$RCH_2NO_2 \longrightarrow RCH{=}NOOH \longrightarrow RCONHOH$$

$$RCH{=}NOONa + C_6H_5COCl \longrightarrow RCONHOCOC_6H_5 + NaCl$$

AMIDES

C. Hofmann (*34*) found that *aliphatic* amides are rapidly converted to hydroxamic acids by means of hydroxylamine or its hydrochloride. Caprolactam was found by the writer to respond to this test also.

$$RCONH_2 + NH_2OH{\cdot}HCl \longrightarrow RCONHOH + NH_4Cl$$

$$\begin{matrix} RCONH \\ \llcorner\!\!\lrcorner \end{matrix} + NH_2OH{\cdot}HCl \longrightarrow \begin{matrix} RCONHOH \\ \llcorner NH_2{\cdot}HCl \end{matrix}$$

Procedure.—Boil 0.1 g. of an amide with 0.5 cc. of normal hydroxylamine hydrochloride solution (in methanol) for a few minutes. Cool. Add a drop of ten per cent. ferric chloride.

An alternative test which may be successful when that just given fails, as, for example, in the case of acetanilide, depends on the conversion of the amide to an ester by means of an alcohol (*n*-amyl is useful) and concentrated sulfuric acid.

$$CH_3CONHC_6H_5 + C_5H_{11}OH \longrightarrow CH_3COOC_5H_{11} + C_6H_5NH_2$$

Procedure.—Gently reflux a mixture of 0.5 g. of acetanilide, 2.0 cc. of *n*-amyl alcohol, and 0.5 cc. of concentrated sulfuric acid for five minutes. Cool and add about 10 cc. of ice water. Test the alcohol layer for ester in the usual way.

Olivieri-Mandala (*29*) reported that *aromatic* amides are converted directly to ferric hydroxamates by treatment with hydrogen peroxide in the presence of ferric chloride.

$$ArCONH_2 + H_2O_2 \longrightarrow ArCONHOH + H_2O$$

Procedure.—Suspend a few milligrams of an aromatic amide in 5 cc. of water. Add a drop of ten per cent. ferric chloride and a few drops of three per cent. hydrogen peroxide. The color develops slowly in the cold or may be hastened by heating. The product is not stable in the presence of the oxidizing agent. Organic solvents interfere with the test.

CYANATES

Just as ammonium chloride reacts with potassium cyanate to form urea so hydroxylamine hydrochloride reacts with this salt to form hydroxyurea—a hydroxamic acid. The latter gives a distinctive purplish-blue complex with ferric ion (*35*, *36*).

$$KNCO + NH_2OH{\cdot}HCl \longrightarrow KCl + NH_2CONHOH$$

Procedure.—To an aqueous solution of hydroxylamine hydrochloride add a few milligrams of potassium cyanate and after a moment a drop of ten per cent. ferric chloride.

Note: Werner (*36*) tests for urea by heating it in a test-tube and examining the sublimate formed for ammonium cyanate by the procedure given above. An alternative procedure involves heating urea with phosphorus pentoxide and passing the gases containing cyanic acid (HN=CO) into a solution of free hydroxylamine. Since alkyl isocyanates react with hydroxylamine to form alkyl hydroxyureas (*21*) they may also be detected as hydroxamic acids.

$$RNCO + NH_2OH \longrightarrow RNHCONHOH$$

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CHEMICAL ENGINEERING DESIGN COURSES—*A* SURVEY[1]

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It has been known for some time that wide differences of opinion exist as to the place of chemical engineering design in an undergraduate four-year curriculum. By the questionnaire method, a survey of the chemical engineering courses of approximately forty colleges and of an "ideal" chemical engineering design course as outlined by forty different industrial companies has been made and the results tabulated.

The results show that there is a definite demand for such a course in a four-year chemical engineering curriculum. Many of the differences of opinion would perhaps disappear if the term "design" were redefined. The authors look upon such a course as one which will integrate or correlate the student's previous work in the more fundamental courses. A more descriptive title should be given such a course than the present names of Plant Design or Equipment Design. Replies on the questionnaires indicate that some title such as "Chemical Plant Equipment and Layout" or "Process Design and Equipment Selection," or "Process Design, Equipment Selection, and Plant Layout" would be more descriptive of the courses as they are now taught. Such titles would serve to clarify a situation which has arisen from the broad definition of the word "design."

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IT HAS been known for some time that wide differences of opinion exist as to the place of chemical engineering design in an undergraduate four-year curriculum. Some colleges have offered a course in plant design, some a course in equipment design, some have offered both, and some have not offered any separate course in design. A portion of this last group have felt that a four-year period was too short to cover adequately the more fundamental subjects of the curriculum, and hence, have not allotted time to the more professional subject of design. Certain others have felt that sufficient design was already being taught in the unit operations course. Referring to the first edition of the text, "Principles of Chemical Engineering" by Walker, Lewis, and McAdams, in a paper entitled, "Development of Chemical Engineering Education in the United States,"[2] Newman[3] states, "This book was a textbook of the 'Unit Operations' and dealt with the rational quantitative design of chemical engineering equipment." The fact that this text does deal with quantitative design, perhaps explains why some chemical engineering departments have felt that they were giving sufficient design.

The primary purpose of this survey of chemical engineering design courses was to obtain information from both the educational and the industrial fields as to the place of such a course in the four-year chemical engineering curriculum.

Questionnaires were sent to thirty schools which have had their chemical engineering courses placed on the accredited list by the American Institute of Chemical Engineers, and to eleven non-accredited institutions offering a B.S. degree in chemical engineering. The percentage of replies received from the accredited schools was 83.4, whereas only 72.7 per cent. of the non-accredited group returned their blanks. A total of 80.5 per cent. of all questionnaires sent to educational institutions was returned.

It was felt that a complete picture of what a design course should be could not be drawn without consideration of the industries which employ men trained in chemical engineering. Accordingly, forty-three companies were asked to express their opinions. Because the number of industries was small compared with the total number in the United States, they were selected with care so as to be nearly as representative of the whole chemical industry as possible. They consisted of manufacturers of heavy chemicals, process industries, petroleum refineries, equipment manufacturers, solvent producers, steel companies, and, in one case, a consulting chemical engineer. They were distributed throughout the country but were naturally more heavily concentrated in the large manufacturing centers. Replies were received from 74.4 per cent. of the companies, but only 65.1 per cent. filled out the questionnaires.

[1] Presented before the Chemical Engineering Division of the Missouri Section of the Society for the Promotion of Engineering Education, Spring, 1939. Presented at the Summer School for Chemical Engineering Teachers, Pennsylvania State College, June, 1939.

[2] WALKER, LEWIS, AND MCADAMS, "Principles of chemical engineering," 1st ed., McGraw-Hill Book Co., Inc., New York City, 1923, 749 pp.

[3] NEWMAN, *Trans. Am. Inst. Chem. Engrs.*, **34**, No. 3a Supplement (1938).

WHAT IS CHEMICAL ENGINEERING DESIGN?

Perhaps one of the most outstanding facts brought out by the comments included on the returned questionnaires was that there is considerable variation in what is termed "design." It was also obvious that as long as the courses of various colleges continue as outlined on the returned questionnaires, there is little danger of them becoming standardized to the detriment of the profession. Instructors will naturally emphasize those subjects with which experience has made them most familiar.

Various definitions of design are to be found in the dictionaries. Webster states that design is the "purposive planning as revealed in, or inferred from, the adaption of means to an end or the relation of the parts to the whole." Such an all-inclusive meaning of the term "design" was observed by the replies received, both from the educational institutions and industrial concerns. The fact that a large majority of the replies indicated that design courses were chiefly used in the determination of size and the selection of standard equipment and auxiliaries leads to the logical conclusion that design, from the creative standpoint of something new is perhaps a misnomer and that a more descriptive title should be used. The authors look upon such a course as one which integrates or correlates a student's former work in chemistry, unit operations, mathematics, physics, and mechanics. In short, it should tie together four years of undergraduate study in such a way that the student may be able to see the forest instead of merely the trees. A further study of comments on the questionnaires showed that there is considerable overlapping in the topics taught in plant and equipment design.

The tabulated data from both the educational institutions and the industrial concerns are shown in Table 1.

The authors selected only those topics which were known to be taught by some design instructors in compiling the list of subjects which might be covered under items seven and ten of the questionnaires. That this list was not complete is shown by the two following lists made up from the comments or additions by the individuals filling out the forms. Approximately one-half of each of these lists was suggested by the colleges, and the other half by the industrial concerns. No conclusions can be drawn as to the relative importance of any of the items mentioned. On the other hand it should be stated that many of them appeared on several different questionnaires.

ADDITIONAL TOPICS (POSSIBLE) FOR INCLUSION WITH PLANT DESIGN

(Question 7, Table 1)

(*a*) Market study.
(*b*) Raw material study.
(*c*) Office space, lavatories, showers, space and equipment for employee's comfort.
(*d*) Study available transportation facilities, railroad spurs, trucking, and so forth.
(*e*) Allowance of facilities for plant growth and flexibility.
(*f*) Required specials (special problems resulting from general problems).
(*g*) Consider materials for construction from practicability, corrosion, and erosion standpoint.
(*h*) Heat and weight balances.
(*i*) Waste disposal.
(*j*) Control instruments including automatic meters and how they should be included in the original design.
(*k*) Water supply.
(*l*) Process steam.
(*m*) Work simplification through plant and equipment layout.
(*n*) Maintenance.
(*o*) Safety work and accident prevention.
(*p*) Applications of heat and power. Waste heat recovery.
(*q*) Presentation of specifications to manufacturers and analysis of manufacturer's proposals.

ADDITIONAL TOPICS (POSSIBLE) FOR INCLUSION WITH EQUIPMENT DESIGN

(Question 10, Table 1)

(*a*) Efficiencies one may expect from various equipment.
(*b*) High pressure equipment (mentioned by a number of industries).
(*c*) Continuous proportioning devices.
(*d*) Reaction vessels such as sulfonators and nitrators.
(*e*) Gas-making equipment.
(*f*) Plastic equipment.
(*g*) Refrigeration equipment.
(*h*) Agitation.
(*i*) Vacuum equipment, jet condensers.

A STUDY OF TABULATED ANSWERS

It is interesting to note that a larger percentage of the industrial concerns than universities believe that a design course should be included in a four-year chemical engineering curriculum. Approximately one-third of the colleges replying have no separate design course, and approximately one-fifth believe that no separate course in design is advisable in the four-year curriculum. Certain replies might have been influenced by the fact that many of the colleges teach unit operations in the senior year; consequently the students are not prepared for a general design course. Eighty-nine per cent. of the industries replying believe that such a course should be given.

The replies from industry indicate approximately one more semester credit hour should be devoted to design than the colleges believe should be given. The time which the industrial replies indicate should be devoted to design is two semester hours greater than the average actually offered by the "average" college giving a course in design. It must be remembered, however, that the men from industry have not been up against the problem of arranging curricula in most cases.

No definite conclusions can be drawn as to how the time devoted to design should be distributed between plant and equipment, except, perhaps, that both should be offered in approximately equal amounts. The results shown in Table 1 for question three do show a slight balance in favor of equipment by both the colleges and the industries. This would perhaps indicate that more time should be devoted to equip-

TABLE 1

Number	Questions	Number of replies considered	Colleges	Number of replies considered	Industries
1	Time devoted to design in a four-year Chemical Engineering course Semester hours (average credit) per four-year course	33	30.3 per cent. (10) No course 69.7 per cent. (23) Have course 3.18 hours	0	Question 1 to colleges only
2	In your opinion, should time be devoted to a design course in a four-year undergraduate curriculum in chemical engineering? If so, how much? Semester hours (credit) per four-year course	33	Yes 72.7 per cent. (24) No 18.2 per cent. (6) No answer 9.1 per cent. (3) 3.94 hours	28	Yes 89.3 per cent. (25) No 10.7 per cent. (3) 4.85 hours
3	In your opinion, should more emphasis be placed on plant design or equipment design? Indicate percentage of each	24	Average use of time in plant design 47.7 per cent., equipment design 52.3 per cent.	21	Average use of time Plant design 40.8 per cent. Equipment design 59.2 per cent. In addition four favor plant design, two favor equipment design, one gave no answer
4	What text is used? (Some indicated more than one text)	23	Vilbrandt 12 Perry 5 Literature 4 Experience 9 Walker, Lewis, *et al.* 1 Badger and McCabe 1 Tyler 1 Plant Note-Book 1 Machine Design text 1	0	Question 4 to colleges only
5	Is (should)* an attempt (be)* made to include cost investigation along with design?	33	Yes 72.7 per cent. (24) No—none No answer 27.3 per cent. (9)	28	Yes 78.6 per cent. (22) No 14.3 per cent. (4) No answer 7.1 per cent. (2)
6	Are (should) the following topics (be) included in the chemical engineering design course?				
	(*a*) Principles of plant location	33	Yes 72.7 per cent. (24) No 9.1 per cent. (3) No answer 18.2 per cent. (6)	28	Yes 82.2 per cent. (23) No 7.1 per cent. (2) No answer 10.7 per cent. (3)
	(*b*) By discussion		Yes 75.0 per cent.		Yes 82.0 per cent.
	(*c*) By actual problem		Yes 58.5 per cent.		Yes 26.1 per cent.
			Per cent. of those answering yes to (*a*)		Per cent. of those answering yes to (*a*)
			Eight in both (*b*) and (*c*)		Two in both (*b*) and (*c*)
7	A complete plant including,	26(*a*)		30(*b*)	
	(*a*) Foundations		Yes 34.6 per cent. (9)		Yes 53.3 per cent. (16)
	(*b*) Building		Yes 57.7 per cent. (15)		Yes 53.3 per cent. (16)
	(*c*) Drainage		Yes 34.6 per cent. (9)		Yes 66.6 per cent. (20)
	(*d*) Heating		Yes 26.9 per cent. (7)		Yes 60.0 per cent. (18)
	(*e*) Lighting		Yes 34.6 per cent. (9)		Yes 56.7 per cent. (17)
	(*f*) Ventilation		Yes 42.3 per cent. (11)		Yes 66.6 per cent. (20)
	(*g*) Power transmission		Yes 46.2 per cent. (12)		Yes 56.7 per cent. (17)
	(*h*) Selection of standard process equipment		Yes 100 per cent. (26)		Yes 86.6 per cent. (26)
	(*i*) Conveying equipment		Yes 80.8 per cent. (21)		Yes 66.6 per cent. (20)
	(*j*) Special storage facilities		Yes 76.9 per cent. (20)		Yes 66.6 per cent. (20)
8	Selection of size, and the location of, pipe lines for process equipment (gas, water, steam, and so forth)	26(*a*)	Yes 96.1 per cent. (25)	30(*b*)	Yes 86.6 per cent. (26)
9	Flow diagrams	26(*a*)	Yes 96.1 per cent. (25)	30(*b*)	Yes 96.6 per cent. (29)
10	Design of process equipment including,	26(*a*)		30(*b*)	
	(*a*) Heat transfer equipment		Yes 76.9 per cent. (20)		Yes 80.0 per cent. (24)
	(*b*) Kilns and furnaces		Yes 46.2 per cent. (12)		Yes 70.0 per cent. (21)
	(*c*) Evaporators		Yes 57.7 per cent. (15)		Yes 73.3 per cent. (22)
	(*d*) Driers		Yes 57.7 per cent. (15)		Yes 76.7 per cent. (23)
	(*e*) Gas absorbers		Yes 65.4 per cent. (17)		Yes 76.7 per cent. (23)
	(*f*) Extractors		Yes 38.5 per cent. (10)		Yes 56.7 per cent. (17)
	(*g*) Filters		Yes 57.7 per cent. (15)		Yes 63.3 per cent. (19)
	(*h*) Mixers		Yes 23.1 per cent. (6)		Yes 60.0 per cent. (18)

(*) Refers to questions to industries.

(*a*) Of the thirty-three replies, seven gave no course and three gave no answers. However, since some schools giving no course covered part of the items listed in other courses, an average of twenty-six has been taken as a basis of replies for questions 7–12, inclusive.

(*b*) Twenty-seven companies filled out the questionaire. One company sent six answers, making thirty-two answers considered in 7–12, inclusive.

TABLE 1 (*Continued*)

Questions		*Colleges*		*Industries*	
Number		*Number of replies considered*		*Number of replies considered*	
	(*i*) Crushers		Yes 30.8 per cent. (8)		Yes 60.0 per cent. (18)
	(*j*) Distillation equipment		Yes 61.5 per cent. (16)		Yes 76.7 per cent. (23)
11	Air conditioning equipment	26(*a*)	Yes 38.5 per cent. (10)	30(*b*)	Yes 46.7 per cent. (14) Stress 10.0 per cent. Briefly 30.0 per cent. For process 6.7 per cent.
12	If equipment design only would be given, should an attempt be made to coördinate the various pieces of unit operation equipment into a complete process		Answers to question as stated on questionnaire were unsatisfactory	30(*b*)	Yes 90.0 per cent. (27)

ment. On the other hand, certain comments indicated the lack of a sharp line of distinction between plant and equipment design. A number of the individuals replying, however, feel quite strongly on the subject of plant design versus equipment design as indicated by the following quotations.

"The design of unit operation equipment is basic to plant design and, therefore, should be stressed."

"There are possibly a dozen good equipment designers in the country. There is little need for any more."

"Only after years of experience will one enter plant design. Efficiency and speed in representing one's ideas are major objects in design. I think one thorough design is better than much flow sheet and plant design."

"The equipment design is only that portion which the nature of the plant design problem demands. The emphasis is on plant design."

"Equipment is not beyond the young engineer's range of intelligence."

"Although equipment design is very important, it is only in plant design that the proper correlation of a student's previous work can be accomplished to the best advantage."

Table 1 shows a large proportion of the industries in favor of the inclusion of almost every topic listed under questions seven and ten. The per cent. of the colleges in favor of inclusion of the various items runs three to thirty per cent. lower than that of the industries in favor of the same topics. This is entirely in accord with the additional time which the industries believe should be devoted to design. There are several exceptions to this generalization, however, namely questions 7*b*, 7*h*, and 7*i*, which are in the reverse order. The answer to 7*h* may, perhaps, be explained on the basis that some of the men from industry may not have considered the selection of standard process equipment as design. Comments indicated that a large majority of both groups believe that selection of standard equipment should be stressed.

One question which should have been asked on the questionnaire is as follows. Is, or should, an attempt be made to correlate design with experimental process laboratory work? Dodge[4] has indicated one method by which this correlation between laboratory and design might be obtained. Vilbrandt[5] has suggested another method which is perhaps not so comprehensive as that of Dodge. A study of the catalogs and replies from the questionnaire revealed that only five of the forty-one schools receiving the questionnaire carry on this type of work at present. Such correlation is worked out in this type of course by obtaining quantitative data in the laboratory for the process under consideration. This is particularly true in cases in which data are lacking in the literature or are very meager. The data so obtained are then used in making the necessary calculations for the design either of a pilot plant or commercial plant. Undoubtedly, other schools make use of data obtained from routine laboratory work or from research in the design of some special equipment. Some of the collegiate questionnaires contained remarks indicating that their authors believed poor economy of students' time resulted from such an attempted coördination.

A review of the catalogs of the schools to which questionnaires were sent also showed that 14.6 per cent. of the number require one or more courses in machine design—in most cases in addition to the regular chemical engineering design.

A STUDY OF REMARKS

Probably the most interesting part of the results of this survey was contained in the remarks and comments made on the returned questionnaires. In a paper of this type it is impossible to reproduce all of them, hence it will be necessary to generalize and draw such conclusions as are possible.

Table 1, while it contains certain qualitative information as to the content of a chemical engineering design course, shows very little as to the amount of time which should be devoted to a particular subject or as to how heavily it should be stressed. While most of the items under question 7 are included in almost every plant design course, the answers indicated that various individuals put much more stress on some items than others. For example, some included no details regarding a building, others a cost estimate only, while others merely discuss the subject in lecture. Some

[4] DODGE, J. CHEM. EDUC., **15**, 479 (1938).

[5] VILBRANDT, *Ind. Eng. Chem.*, **31**, 253 (1939).

schools choose a broad general problem and then select by calculation each item involved in the particular problem or plant layout.

Obviously it would be impossible to include a complete design of many of the items of equipment mentioned under question 10. Some schools after assigning the broad general problem limit the work by selecting one or more of the items under question 10 for a complete or detailed design. This, again, brings up the question of the definition of "design." A comment taken from one of the questionnaires regarding the design of process equipment states the case very aptly. "If, by 'design' is meant the preparation of details sufficient for fabricating purposes, I do not believe that any of the items herein mentioned can be treated satisfactorily. However, if 'design' refers to the determination of basic sizes and operating conditions, all of the subjects have merit. The relative importance depends upon the industry."

This need for clarification of the term "design" is not entirely new for Professor Hougen in a written discussion of Dr. A. B. Newman's[3] paper writes as follows: "Plant design. Repeatedly your report refers to the necessity of the chemical engineer to design plants. I limit the interpretation of plant design to the ability of selecting equipment, to laying out its arrangement and determining sizes, capacities, dimensions and materials of construction. Others extend the meaning to include the design of structures, involved mechanisms and complicated machinery. Surely adequate preparation to perform the latter tasks cannot be included in a four-year curriculum. The latter skills involve more extensive training in mechanics, structures and machine design than can be granted. A few chemical engineers will become great designers of machines, but should not these duties be left chiefly to the mechanical and structural engineer? Your Committee should clarify this point."

The writer of one industrial reply, who did not believe in offering a design course in an undergraduate curriculum, apparently interpreted the word "design" in the restricted sense, for he says, "It is our belief that in most industrial organizations it is more essential for the chemical engineer to be able to recognize the limitations and advantages of processes and procedures and materials of construction, and to be able to devise improvements in them, than to be able to determine details of construction of buildings and equipment involved. If he is able to write an intelligent (and intelligible) set of design data, then mechanical and civil engineers who have specialized in the design of foundations, structures, and machines can carry out his ideas far more expertly than he could hope to do."

In view of the foregoing comments, would it not be more appropriate and descriptive to rename our present so-called design courses? Replies on the questionnaires indicate that some title such as "Chemical Plant Equipment and Layout," or "Process Design and Equipment Selection," or "Process Design, Equipment Selection, and Plant Layout" would be more descriptive of the courses as they are now taught.

SUMMARY

The results of the present survey may be summarized under the following headings:

(1) There is a definite place and need for a "design" course in the four-year chemical engineering curriculum.

(2) The term "design" as it is now applied to chemical engineering design courses should be clarified.

(3) A more descriptive title should be given such a course.

ACKNOWLEDGMENT

The authors wish to express their appreciation to the large number of individuals and companies that responded to the questionnaire. The complete manner in which many of the replies were worded was indeed gratifying.

ENGLISH UNIT CALCULATIONS *in* GENERAL CHEMISTRY

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Chemical engineers need to be familiar with both metric and English systems of measurement. Computations in English units, though usually avoided in chemistry courses, are not difficult, and chemistry problems stated in these units require few more conversion factors than metric system problems. Introduced into first-year chemistry, these computations are of decided advantage to the beginning chemical engineer and to other students as well; they

help lay the foundation for engineering calculations later, and they help the student connect his chemistry with everyday life.

Several types of problems may be used. A classification, illustrative problems with answers, and a table of conversion factors are included.

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ENGLISH units are used in practically all engineering work in the United States, and practice in these calculations is an essential part of the training of an engineer. Computations of this sort can and should be included even in a beginning course in general chemistry, but, unfortunately for the student engineer, mention of chemical engineering units is usually omitted. This omission probably results from two things. (1) Most available chemistry texts do not include English unit calculations. (2) Practically all laboratory work in chemistry, because of the obvious advantages of the metric units, is conducted in the C.G.S. system.

The fact remains, however, that all engineers use the English system, and that the chemical engineer must learn to deal in pounds, gallons, and cubic feet as well as in the chemist's grams and cubic centimeters. Chemistry problems stated in the engineering units of pounds, gallons, and cubic feet involve but little more than just substitution of pounds for grams in the more customary type of chemistry problem, and familiarity with these essentially simple calculations gives much helpful introductory training with the chemical calculations of chemical engineering.

Altogether there are five types of English unit problems that really belong in a first-year chemistry course.

(1) The most important type of problem is that involving simple stoichiometric relationships, and problems dealing with materials actually used in commercial processes can be made a helpful part of the descriptive work of the course. Some calculations should be made with yields less than perfect and purities less than one hundred per cent.

(2) Problems involving volumes of materials are often found confusing, probably because the student fails to distinguish sharply in his own mind between two properties of matter, "mass" and "volume." To a large extent this confusion is avoided in the English system because conversion factors are always necessary, and by using specific gravities (avoiding "densities") less confusion results even with problems in the metric system. The conversion factors necessary for problems of this sort must, of course, be given to the students, who in general know at least part of them already. It should be emphasized that it is not necessary for the student to memorize tables and that conversion factors will always be available.

The factors necessary for problems involving specific gravities are, to slide rule precision,

1 gallon of water weighs 8.33 pounds

1 cc. of water weighs 1 gram

1 cubic foot of water weighs 62.3 pounds (all at 20°C.)

(3) Simple Boyle's law computation using English units of pressure can easily be included along with other gas law problems. By including pressure values in "gage" readings (above atmospheric pressure) as well as absolute values, the problems are made no more difficult, for the conception of absolute pressure is apparently an easy one to grasp. Such a procedure helps materially with the apparently more difficult concept of an absolute temperature.

Necessary factors for this type of problem are

1 atmosphere = 760 mm. of mercury
14.7 pounds per square inch
29.92 inches of mercury

(4) Problems including Fahrenheit temperature should be included with other gas law problems. Using absolute scales in both Fahrenheit and Centigrade units (degrees K or Kelvin, Centigrade plus 273; and degrees R or Rankine, Fahrenheit plus 460) avoids conversions, and gas law computations remain essentially a straightforward process. Since Centigrade temperatures are used in some chemical processes (practically the only exception to the almost universal use of English units in engineering practice), it is all the more necessary that the chemical engineer be able to think freely in either scale, avoiding bothersome, unnecessary conversions.

The necessary temperature factors are

Absolute zero = −273°C. = −460°F.

(5) Problems using the pound molecular volume are important. The pound molecular volume, three hundred fifty-nine cubic feet, is strictly comparable to the gram molecular volume, 22.4 liters. It is extremely useful for computing gas densities, and in stoichiometric relations when a gas is involved.

These problems, some of which are illustrated, are not intended to displace the absolutely necessary work in metric units, but are supplementary to this. The chemical engineer must be able to use either system of measurements; it happens that the English system is the one commonly neglected in first-year chemistry.

While these calculations are primarily for the engineer, they have decided value for any beginning student. Working problems about real things helps dispel any impression, too often gained, that chemistry deals with something in a watertight compartment and with no relation to anything else. Regardless of pedantic views, chemistry has an objective field of inquiry into the real things of ordinary life. Chemical calculations about ordinary things in ordinary units make chemistry more nearly real and living to the ordinary student. Surely this should not be beneath the dignity of even the most formalized presentation.

SAMPLE PROBLEMS

(1) How much dry ice can be recovered per ton of coal that analyses 78.5 per cent. carbon, 4.3 per cent. hydrogen, 1.2 per cent. nitrogen, and 2.5 per cent. sulfur, if the scrubbers remove 31 per cent. of available CO_2?

(2) A fire extinguisher holds one pound of bicarbonate of soda. How many cubic feet of carbon dioxide, measured at standard conditions, can this much soda generate?

(3) The gas capacity of the Hindenburg was approximately seven million cubic feet. How many pounds of hydrogen and how many pounds of helium (both at standard conditions) would be required to fill it?

What would have been the loss in lifting power if helium had been used?

(4) A plane that required 1000 pounds of fuel would need how many gallons of gasoline, specific gravity 0.66?

What would be the capacity of its fuel tanks in cubic feet?

(5) One hundred cubic feet of air at a gage pressure of 20 pounds is equivalent to how many cubic feet at 1 atmosphere pressure?

(6) What is the weight of air (dry, at 75°F. and 750 mm.) in a room that measures 20 × 30 × 10 feet?

(7) A tank of chlorine holds 100 pounds of the liquified material. What volume of gas would be produced if this were liberated at 75°F. and 1 atmosphere?

How many gallons of water would this chlorinate if one-half part per million of chlorine were used?

(8) A ton of salt will furnish how many cubic feet of chlorine, measured at standard conditions, assuming 95 per cent. recovery?

(9) What weight of sulfuric acid, specific gravity 1.72, 79 per cent. hydrogen sulfate, can be obtained from 1 ton of sulfur, 98 per cent. pure?

How many gallons is this?

(10) Heats of combustion of fuel gases are often measured with the gases at 60°F., 30 inches of mercury, and saturated with water vapor. What volume would one cubic foot at these conditions become at standard conditions?

FACTORS

1 gallon of water weighs 8.33 pounds
1 cc. of water weighs 1 gram
1 cubic foot of water weighs 62.3 pounds (at 20°C.)
1 atmosphere = 760 mm. of mercury
14.7 pounds per square inch
29.92 inches of mercury
absolute zero = −273° Centigrade
−460° Fahrenheit
1 pound mole of a gas occupies 359 cubic feet (std. cond.)
1 gram mole of a gas occupies 22.4 liters (std. cond.)
453.6 grams = 1 pound
2.54 centimeters = 1 inch
0°C. = 32°F.

ANSWERS TO PROBLEMS

(1) From the equation, 1 atom of carbon gives 1 mole of CO_2
12 lbs. carbon give 44 lbs. CO_2
2000 × .785 = 1570 lbs. carbon give 5770 lbs. CO_2
at 31 per cent. recovery .31 × 5770 = *1780 lbs. Ans.*

(2) From the equation, 1 mole $NaHCO_3$ gives 1 mole CO_2
84 lbs. $NaHCO_3$ give 359 cu. ft. CO_2
1 lb. gives *4.28 cubic feet Ans.*

(3) 7,000,000 cubic feet at standard conditions is
7,000,000/359 = 19,500 pound moles
19,500 lb. moles of H_2 19,500 × 2 *39,000 pounds Ans.*
19,500 lb. moles of He 19,500 × 4 *78,000 pounds Ans.*
Loss in lifting power 78,000 − 39,000 *39,000 pounds Ans.*

(4) 1 gallon of gasoline weighs 8.33 × .66 = 5.5 lbs.
1000 lbs. = 1000/5.5 = *180 gallons Ans.*
1 cubic foot of gasoline weighs 62.3 × .66 = 41 lbs.
1000 lbs. = 1000/41 = *24 cubic feet Ans.*

(5) 100 × (14.7 + 20)/14.7 *236 cubic feet Ans.*

(6) Volume of room 20 × 30 × 10 = 6000 cu. ft., equivalent to
6000 × (32 + 460)/(75 + 460) × (750/760) = 5450 cu. ft. at std. cond.
5450 cu. ft. = 5450/359 = 15.2 moles
15.2 × 29 (apparent M.W. of air) = *442 lbs. Ans.*

(7) One hundred pounds of chlorine = 100/71 = 1.41 pound moles
1.41 × 359 = *506 cubic feet Ans.*
One hundred pounds of chlorine at one-half part per million will chlorinate 200,000,000 pounds of water
200,000,000/8.33 *24 million gallons Ans.*

(8) From the equation, 2 moles salt give 1 mole chlorine
117 pounds salt give 359 cubic feet chlorine
2000 pounds salt give 6130 cubic feet chlorine
at 95 per cent. recovery 6130 × .95 = *5820 cubic feet Ans.*

(9) From the equation, 1 sulfur atom gives 1 mole hydrogen sulfate
32 pounds sulfur give 98 pounds hydrogen sulfate
1960 pounds gives 6000 pounds hydrogen sulfate
6000/.79 = *7600 pounds acid Ans.*
Each gallon weighs 8.33 × 1.72 = 14.3 pounds
7600 pounds is 7600/14.3 = *530 gallons Ans.*

(10) From the tables, the vapor pressure of water at 60°F. is .52 inches
1 × (30.00 − .52)/29.92 × (460 + 32)/(460 + 60)
0.935 cu. ft. Ans.

CORRESPONDENCE

BALANCING OXIDATION-REDUCTION EQUATIONS

To the Editor

DEAR SIR:

I am submitting what I believe is a clever method of balancing oxidation-reduction equations. It may be that this method has been applied or even published before. However, as far as I have been able to determine it has never been used in the past. If such is not the case, my apologies go to the originator.

Whatever credit there should be should go to a freshman chemistry student, Henry Green, of Cleveland, Ohio, who, evidently having some difficulty with the electron-interchange method, resorted to the method explained below. Happening to be an assistant in the course at that time, I was fortunate enough to observe his work and believe that it is of sufficient merit to deserve passing on. So with some further experimentation and application, here are the results and methods.

Let me say in passing that I have met with no situation in which the method is not applicable. No doubt, however, such problems do exist. However, I believe you will agree that there are many quantitative equations which are difficult to balance even by electron interchange. It is my belief that in many of these cases the method suggested below may be profitably employed.

Let us start with a simple example. Suppose that we wished to balance the equation

$$Cu + H(NO_3) \longrightarrow Cu(NO_3)_2 + NO + H_2O$$

Now let the unknown coefficients be a, b, c, and d as we go from left to right. Looking at the elements and their subscripts we get

Equation 1 from copper.....$a = c$
Equation 2 from nitrogen.....$b = 2c + d$
Equation 3 from hydrogen.....$b = 2e$
Equation 4 from oxygen .....$3b = 6c + d + e$

It is now apparent that it will probably be the simplest to resolve all values in terms of "a." Thus we have directly that $c = a$. But $b = 2e$ (Equation 3). Since $e = 3b - 6c - d$ (Equation 4) and $d = b - 2c$ (Equation 2), we have by substituting $e = 3b - 6c - b + 2c$. But $e = {}^1/_2b$ and $c = a$. Thus ${}^1/_2b = 3b - 6a - b + 2a$ or $b = {}^8/_3a$. Then from Equation 2 we have ${}^8/_3a = 2a + d$ or $d = {}^2/_3a$. Then $e = {}^1/_2b$ (Equation 3) or, since b has been found to have a value of a, then $e = {}^4/_3a$.

So we now have $b = {}^8/_3a$, $c = a$, $d = {}^2/_3a$, and $e = {}^4/_3a$. Letting "a" equal unity, we have

$$Cu + {}^8/_3HNO_3 \longrightarrow Cu(NO_3)_2 + {}^2/_3NO + {}^4/_3H_2O$$

and clearing fractions:

$$3Cu + 8HNO_3 \longrightarrow 3Cu(NO_3)_2 + 2NO + 4H_2O.$$

A slightly more difficult example might be the treatment of phosphorous acid to produce metaphosphoric acid and phosphine. We have as reactants

$$H_3PO_3 \longrightarrow HPO_3 + H_2O + PH_3$$

Equation 1 from hydrogen.....$3a = b + 2c + 3d$
Equation 2 from phosphorus.....$a = b + d$
Equation 3 from oxygen..... .....$3a = 3b + c$

Here it seems more logical to resolve in terms of "c." It is known that (Equation 2) $a = b + d$. We can then substitute in Equation 3 so that $3b + 3d = 3b + c$. Canceling $3b$ on each side we have $3d = c$ or $d = {}^1/_3c$.

Subtracting Equation 2 from Equation 1 we have, canceling "b" in each equation that $2a = 2c + 2d$. But $d = {}^1/_3c$ so $2a = 2c + {}^2/_3c$ or $a = {}^4/_3c$. Now solving for b in Equation 2 we have ${}^4/_3c = b + {}^1/_3c$ or $b = c$.

Now we have $a = {}^4/_3c$, $b = c$ and $d = {}^1/_3c$. Letting "c" equal unity we have

$${}^4/_3H_3PO_3 \longrightarrow HPO + H_2O + {}^1/_3 PH_3,$$

or clearing fractions we have

$$4H_3PO_3 \longrightarrow 3HPO_3 + 3H_2O + PH_3$$

And finally one involving seven different compounds—

$$MnO_2 + NaCl + H_2SO_4 \longrightarrow Cl_2 + Na_2SO_4 + MnSO_4 + H_2O$$

Equation 1 from manganese.....$a = f$
Equation 2 from chlorine. .....$b = 2d$
Equation 3 from sodium.....$b = 2e$
Equation 4 from the sulfate radical.....$c = e + f$
Equation 5 from hydrogen.....$c = g$
Equation 6 from oxygen.....$2a = g$

Since it appears simplest to resolve in terms of "a" we have directly that (Equations 1 and 6) $f = a$ and $g = 2a$. From Equation 5 we have $c = 2a$. Then from Equation 4 we have $2a = e + a$ or $e = a$. But $b = 2e$ (Equation 3) so $b = 2a$. Since $b = 2a$, then $d = a$ (Equation 2). Now we have $b = 2a$, $c = 2a$, $d = a$, $e = a$, $f = a$, and $g = 2a$. Now let "a" equal unity and we have directly

$$MnO_2 + 2NaCl + 2H_2SO_4 \longrightarrow Cl_2 + Na_2SO_4 + MnSO_4 + 2H_2O$$

And there it is. Although in some cases the method may appear cumbersome, one is surprised to see how quickly one can develop the knack of securing different combinations, and quickly bring order out of the different equations. It is apparent that the more elements which are involved in the reaction, the more easily the problem lends itself to solution. The value is especially apparent in cases where many molecules are involved in the reaction.

Anyhow, it is lots of fun solving them in this manner, and at times the fun can be put to practical use.

GERALD BARTHAUER[1]

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ANDREW WITTMAN—DISCOVERER OF ZINC

To the Editor

DEAR SIR:

R. D. Billinger in a recent paper (*1*) in THIS JOURNAL has ably described the early discovery and subsequent history of zinc in the Lehigh Valley. In this article it was declared that the true character of the ore was not definitely known until Mr. W. T. Roepper examined it and identified it as calamine.

The present writer in a short paper (*2*) on the same subject made a similar statement.

Richmond E. Myers in a lengthy article (*3*) states that Andrew Wittman conducted several experiments in 1845 and managed to obtain a few globules of metal which he could not identify. This seems unlikely. It is difficult to believe that one sufficiently skilful to obtain a sample of metal from an ore would be at a loss as to how to identify the metal if it was not immediately recognized from its physical properties.

In order to settle the matter one way or another the writer has, during the past several years, examined a large portion of the printed material extant on the subject and has come to the conclusion that Andrew Wittman was not only the first person to identify the ore as a zinc ore but was also the first one to obtain some of the metal.

A very interesting paragraph which accurately describes the true sequence of events and which sums up the present writer's views in the matter is to be found in the "History of Lehigh Co., Pa.," by Charles R. Roberts, *et al.* (*4*). As this information is hidden in what really amounts to a genealogical record one feels

that it should be made more readily available to all interested in the history of the Friedensville zinc deposits.

The paragraph in question, which follows, is found on page 938 of Chapter XLIV, "Upper Saucon Township," compiled by Frank B. Heller.

"The discovery of zinc at Friedensville (like many another important discovery) is generally accredited to the one who first made it known rather than to the real discoverer. The following develops the true process of its discovery, and will serve to place the honor where the same is due. On the west side of the road leading from Friedensville to Bethlehem, at a distance of about one hundred fifty perches[1] from the base of the Lehigh mountain, in the middle of a field fertile and productive in every other part, there was a depression resembling in shape a large bowl, about three hundred feet in diameter, and about twelve feet in depth. On this spot, with the exception of a few sickly weeds, no vegetation would grow. This sterility was attributed by many to the presence of mineral substances in the soil deleterious to plant life, but beyond this no one ventured. The place was visited by one of the State geologists, but he made no report of his observations. On the edge of the hollow a number of bowlders, resembling limestone, projected from the surface. These Mr. Ueberroth, the owner of the land, attempted to convert into lime by the usual process, but failed, the whole mass melting together in the kiln. After this the place was made a repository for rubbish and the stones picked from the farm, and so it remained until 1845, when Mr. Andrew K. Wittman was called as surveyor to trace a line between lands of Mr. Ueberroth and one of his neighbors. While thus engaged his attention was attracted to these bowlders, and he took pieces of them along home to add to a collection of minerals he was then forming. Taking much interest in minerals, and being of an investigating turn, he resolved upon a test of his recently acquired specimen, resorting first to the blowpipe, then to acids, and finally to the crucible. By the latter process he succeeded in obtaining about two ounces of metal, which, from his knowledge of metals, he knew to be zinc. On the following day he met Mr. Ueberroth, told him of his discovery, and gave him a portion of the metal. On the afternoon of the same day Ueberroth visited Bethlehem, and stopped at Leipert's Hotel, where he exhibited his metal to some friends. Among the sojourners at the hotel at the time was Professor T. H. Roepper,[2] who overheard the conversation between Ueberroth and his friends, saw the metal, and lost no time in proceeding to Friedensville and getting a supply of ore, of which he soon succeeded in making brass by mixing it with copper. Roepper then went to Philadelphia, made the discovery known, and has since been accredited with it by nearly every one who undertook to write about it, while Mr. Wittman, the real discoverer, has hardly been noticed or mentioned by any."

[1] A perch is equivalent to one rod (sixteen and one-half feet).

[2] Should be W. T. Roepper. The same mistake is found in M. S. Henry, "History of the Lehigh Valley," Bixler & Corwin, Easton, Pa., 1860.

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(3) MYERS, R. E,, "The story of the zinc industry in the Saucon Valley," *ibid.*, **10**, 17, 33, 56 (1935). Three parts. Contains a bibliography of twenty-six titles.
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E. W. BLANK

COLGATE-PALMOLIVE-PEET COMPANY
JERSEY CITY, NEW JERSEY

THE CHEMISTRY TEACHERS CLUB OF NEW YORK—A WORTH-WHILE ORGANIZATION

To the Editor

DEAR SIR:

This Club was organized by a group of young chemistry teachers on March 20, 1902. It has functioned continuously since that time. At present two hundred fifty men and women who teach chemistry in the high schools and colleges of the metropolitan area are enrolled in the Club.

The objectives of the founders of this organization were of three types. It was planned to use the Club for professional growth of the members, for promoting fellowship among the chemistry teachers of the area, and for influencing the proper authorities toward a recognition of the importance of chemistry as a part of the school curriculum.

The results obtained in these three fields of endeavor have surpassed the expectations of the founders to a considerable degree. In promoting professional growth the Club has visited ninety-two chemical manufacturing plants of over fifty different types, seven industrial laboratories, three research institutes, and three science museums. Over seventy-five classroom experiments and demonstrations have been exhibited before the Club. Many of these demonstrations may be found in the chemistry textbooks written by members of the Club. Some sixty-odd speakers, including specialists of national repute, have addressed the Club on chemical and pedagogical topics.

The yearly schedule of programs usually consists of a social evening, a science luncheon, an evening devoted to technics of teaching, four lectures on chemistry, two or three plant visits and recently an outing or picnic has been added.

Those who participate in these activities receive inspiration and information equal or superior to the average "alertness" course.

Abstracts of the speeches and plant visits are sent

to the members who are unable to attend meetings. Most of the income from the two-dollar dues paid by the members is spent for paper and postage.

In promoting fellowship the Club has been equally successful. Each meeting is preceded by an informal dinner to which all members are invited. An out-of-town excursion is conducted yearly. One or two meetings are planned with the social aspect as the dominant feature.

As far as influencing the trend in chemical education, the Club through its committees has initiated the introduction of non-college chemistry courses into the curricula of the various local schools. It has succeeded in bringing to the College Entrance Board a better understanding of the high-school point of view. Modifications of the New York State Regents' syllabus in chemistry have been brought about by the Club's syllabi committees. The Club has aided in establishing qualifying standards for the position of chemistry teacher in the New York City System. Similar standards for the position of chairman of the chemistry department in the city schools have followed principles advocated by the Club. School administrators frequently consult members of the Club before deciding policies regarding chemistry teaching.

Other work of this organization has included surveys of the schools represented among the membership as to the number of pupils, equipment, teaching load, and so forth. A committee has interested a large company in producing motion picture film suitable for chemistry teaching.

The splendid success of the Club has been due in a large measure to the methods used in selecting officers and transacting business. A treasurer is nominated each year by a standing committee. He is nominated and elected successively until he becomes president if his services are satisfactory and his personal interest permits. This insures a well-trained man to head the Club. No president has been nominated for a second term thus far. All past presidents become life members of the advisory committee. The function of this committee is to assist the executive committee in conducting the Club activities.

The executive committee is composed of the four usual officers and the most recent past president. This group conducts all the routine business. Only special business is brought up at the meetings. This permits practically the entire period to be used in social or informational activities.

It seems to the writer that no teacher of chemistry can afford to fail to associate with organizations of this type whenever possible. Also, it seems that this particular Club has evolved some technic, outlined above, which others may find useful if they have not already discovered them.

ERNEST B. WILSON (*President, 1938–39*)

ERASMUS HALL HIGH SCHOOL
BROOKLYN, NEW YORK

AN IMPROVED HEAT OF VAPORIZATION DEMONSTRATION

VINTON R. RAWSON[1]

Scarsdale High School, Scarsdale, New York

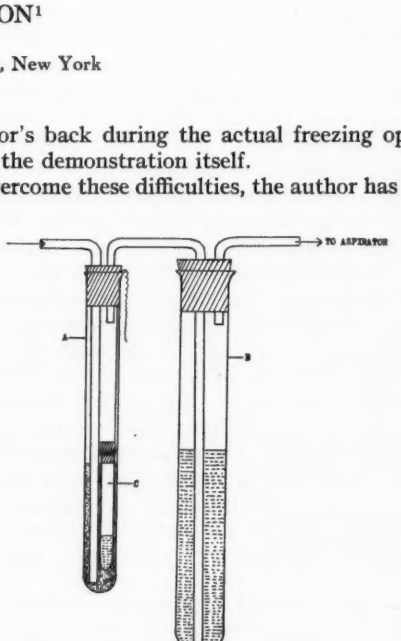
THE classical experiment to demonstrate heat of vaporization is to freeze a wet watch glass or small beaker to a block of wood by the rapid evaporation of ether or carbon disulfide placed in the glass vessel. This demonstration has several disadvantages.

(1) The layer of ice formed between the glass and wood is usually so thin that it quickly melts. In a large class, only a few of the pupils actually see that ice has formed.

(2) The fumes of ether or carbon disulfide, blown into the air of the room during the evaporation process, make many pupils ill. In fact, after the experiment has been repeated several times for the benefit of many sections, the odor of the air in the room is almost unbearable.

(3) Most high schools do not have a hood placed at the front of the lecture room so that the fumes may be conducted up a flue. However, if such a fortunate condition exists, the pupils get a better view of the instructor's back during the actual freezing operation than of the demonstration itself.

To overcome these difficulties, the author has devised



[1] Present address: White Plains High School, White Plains, New York.

the following demonstration. The accompanying diagram shows the set-up of the apparatus. Test-tube *A* measures ten inches by one inch and contains 25 ml. of ether. Suspended in the ether by a stout cotton thread is a four inch by one-half inch test-tube (*C*) which is filled to a depth of one inch with distilled water. The thread is useful in later withdrawing it from the ether. Test-tube *B* measures twelve inches by one and one-half inches and is half filled with alcohol. The short bent glass tube leading from tube *B* is connected to an aspirator.

To operate this apparatus, the aspirator is slowly turned on. Air enters the ten-inch test-tube and bubbles through the ether, vaporizing it. The ether vapor is carried over into the alcohol, and is absorbed. After the air bubbles have agitated the alcohol, the aspirator may be fully turned on. This causes rapid evaporation of the ether, and within a short time, the water in the small tube is frozen. The pupils actually see the water freeze, and later may examine the tube of ice, which does not melt for several minutes. Even at the end of several demonstrations, the odor of ether in the air of the room is scarcely noticeable. The waste water from the aspirator may be conducted directly to the sink outlet by means of a large diameter metal pipe. This further cuts down the amount of ether vapor entering the air of the room and prevents splashing of the water. There is apparently little loss of efficiency in the aspirator. If the glass tube between the two large test-tubes is cut in two and connected by a short length of rubber tubing, the removal of the stopper from test-tube *A* is facilitated.

A CONVENIENT LABORATORY STILL

EDWARD RIETZ[1]

Howard College, Birmingham, Alabama

THE still described in this article was constructed as a makeshift when the commercial still in the laboratory broke. It was found to have such ease of operation and such reliability of performance, however, that it was retained for the production of distilled water for research students.

A diagram of the still is shown. The reader will observe that it is essentially a Florence flask equipped with a constant leveling device.[2]

Water is supplied to cup *B* by a tube *A* at a rate slightly greater than the rate of distillation, the excess passing through the overflow and into the drain through *C*. As water is distilled in flask *F*, the level momentarily drops below the level of the water in cup *B*, but syphoning restores the levels.

Tube *E* is provided to permit removal of the air bubbles which come out of solution of the water and which would "break" the syphon should they be permitted to accumulate. They are removed when necessary (about once a week) by sucking at *G*, a tube which is clamped with a pinch-clamp while the still is in operation.

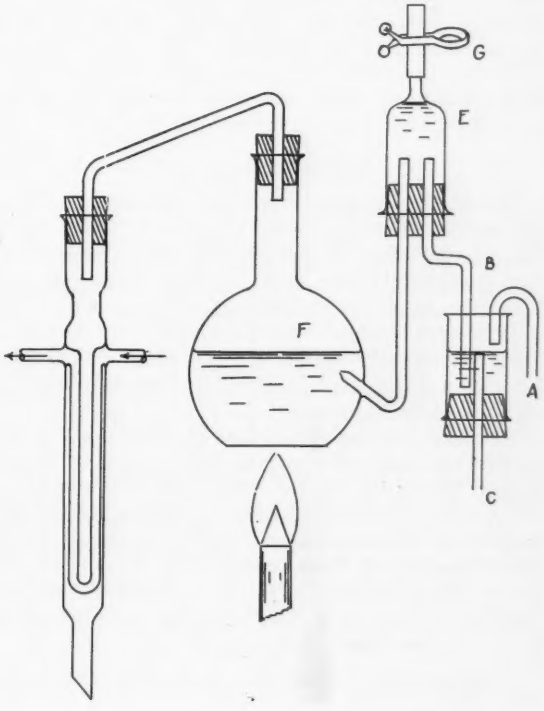
Since the union of the tube to the flask requires moderate skill in glassblowing, the preparation of the joint will be described.

A six-inch section of 14-mm. pyrex tubing is constricted to 4 mm. at one end and is joined to a six-inch section of 8-mm. pyrex at the other end. A bulb about 20 mm. in diameter is blown about one inch from the constricted end. A 15–17-mm. hole is then blown into a one-liter Florence flask about two inches from the bottom. The 14-mm. tube is then inserted into the hole at about a 45° angle and is clamped into position. The seal is made with a hand torch. The bends are made as indicated.

It will be noted that the seal is introduced at some distance from the base of the flask. This avoids strains near the bottom—the most vulnerable section.

The still, once in operation, operates without attention and consistently produces one and one-half to two liters per hour when adequate heat is applied.

The author acknowledges the helpful suggestions of Mr. Norman H. Horton, a student at Howard College.



[1] Present address: The University of Chicago, Chicago, Illinois.

[2] FINDLAY, "Practical physical chemistry," 6th edition, Longmans, Green & Co., New York City, 1936, page 31.

HIGH-SCHOOL NOTES

ELBERT C. WEAVER[1]

Bulkeley High School, Hartford, Connecticut

NATIONAL ORGANIZATIONS

THE *National Committee on Science Teaching* has held four meetings. Six sub-committees are at work on a reorganization program of science in the first fourteen grades. Some material which these committees are developing has been sent to a great many teachers for evaluation and suggestions. The Committee will meet at St. Louis, Feb. 23–24, 1940. It is composed of five representatives of the National Education Association and one member each from ten organizations interested in science education, including the Division of Chemical Education of the A. C. S. Dr. Ira C. Davis, University High School, Madison, Wisconsin, is acting as chairman of the Committee. Many science teachers about the country are acting as consultants and are working on sub-committees.

The *Division of Chemical Education's Committee on High School Chemistry* is H. W. Baker, Instructor in Chemistry, James Ford Rhodes High School, Cleveland, Ohio; Nicholas Cheronis, Wright Junior College, Chicago, Illinois; R. E. Davis, Head of Chemistry Department, Lane Technical High School, Chicago, Illinois; Robert L. Ebel, Instructor in Chemistry, Edison Institute, Dearborn, Michigan; Elbert C. Weaver, Instructor in Chemistry, Bulkeley High School, Hartford, Connecticut; Martin V. McGill, Instructor in Chemistry, Lorain High School, Lorain, Ohio, Chairman. This committee will meet as a group at the Cincinnati meeting of the A. C. S.

REGIONAL ACTIVITIES

The *Northeastern Ohio Chemistry Teachers Organization* met at Hubbard, Ohio, December 2, 1939. A trip through the plant of the Ohio Leather Company at Girard and talks by Dr. H. S. Booth of Western Reserve University and Dr. Scudder of Youngstown (Ohio) College were features. "Neo-Chemto," this organization, is coöperating with the Division of Chemical Education committee in developing a course of study in high-school chemistry.

The *New England Association of Chemistry Teachers* held its one hundred ninety-seventh meeting at Northeastern University, Boston, Massachusetts, on December 9, 1939. Professors Luder and Zuffanti of the host institution delivered papers, and John Hogg, Exeter (New Hampshire) Academy described present chemistry teaching in England. Dr. H. H. Sheldon, American Institute of the City of New York, discussed the expansion of the Institute's club program.

Other scheduled meetings which readers of THIS JOURNAL may attend are January 6, Attleboro, Massachusetts, trip to the Balfour Company, jewelry manufacturers, and a talk by Dr. J. W. Irvine of the Massachusetts Institute of Technology, on "Synthetic Radioactive Elements"; February 3, Milton Academy (Massachusetts); March 2, Wilbraham Academy (Massachusetts); April 5, Westerly, Rhode Island; May 4, Andover Academy (Massachusetts).

The *New England Association of Chemistry Teachers* is planning another summer conference. Theodore W. Sargent, Swampscott High School, Swampscott, Massachusetts, Chairman, announces August 13–16 at the University of Maine for the 1940 conference.

INQUIRY

"Energy can neither be created nor destroyed. Work is a form of energy." If you wind up a clock spring you do work. Now tie a platinum wire about the spring in order that it cannot expand. Slowly dissolve the spring in acid from the bottom to the top. *Where* does the energy go?—J. D. LONGANECKER, Uniontown, Pennsylvania.

AN EXPERIMENT FOR THE DETERMINATION OF TRANSFERENCE NUMBERS BY ELECTROMOTIVE FORCE METHODS—A CORRECTION

Some errors appear in this article by C. M. Mason and E. F. Mellon (J. CHEM. EDUC., **16**, 512–3 (1939)). The corrections are as follows:

Equation 1 should read:

$$E_I = 2\frac{RT}{nF}\ln\frac{a_2}{a_1}$$

Equation 2 should read:

$$E_{II} = 2T_a\frac{RT}{nF}\ln\frac{a_2}{a_1}$$

Cell III should read:

Ag, AgCl, HCl (a_1), H_2 (1 atm.)...H_2 (1 atm.), HCl (a_2) AgCl, Ag

The electrodes in the figure should be labeled *A*, *B*, *C*, and *D* from left to right.

T_a and T_c in Columns 6 and 7 in Table 1 should be interchanged, the higher value being that for T_c.

[1] Present address: Polytechnic High School, Long Beach, California.

RECENT BOOKS

VOLUMETRIC ANALYSIS. *A. J. Berry*, M.A., Fellow of Downing College and University Lecturer in Chemistry, Cambridge. Fifth edition. Cambridge University Press, London, 1939. (The Macmillan Company, New York City). vii + 196 pp. 9 figs. 14 × 21.5 cm. $2.50.

As the reader would naturally anticipate, this little book on volumetric analysis by Professor Berry, whose scholarly achievements have long since been recognized, presents some very attractive features. It differs from the typical analytical text of the present day, however, in so far as it is comparatively free from theoretical matter. In truth, underlying principles are given exposition in connection with certain processes, and these expositions are to be found here and there among the pages; yet there is no apparent attempt to build a continuous framework of physical chemistry. The foregoing statement is not to be taken as unfavorable criticism: the author has thus been able to bring into small compass a great variety of methods; consequently the student may proceed from the general to the particular, and, as is more important, awake to an appreciation of the immense scientific and utilitarian value of volumetric procedures—pedagogic results that can hardly be expected to accrue from the perusal of a small manual that is but a collection of a few particular cases.

As the author says in his preface to the current edition, the volume is intended to be one of intermediate scope. It is composed of fifteen chapters, some tabulated data, and an index. The first chapter is introductory in its nature. The next seven (Chapters II to VIII, inclusive) deal with the ordinary volumetric processes: namely, those that depend upon oxidations (and reductions), precipitations, and neutralizations. The remaining chapters embody: (IX) the theory of indicators and hydrogen-ion concentration, (X) unclassified volumetric determinations, (XI) special applications of volumetric methods, (XII) actual examples (volumetric only), (XIII) simple gravimetric determinations, (XIV) modern developments in volumetric analysis, and (XV) analysis of gases.

In the reviewer's opinion, the work now under consideration, like other chemical textbooks, exhibits some shortcomings. A few of these, taken haphazardly, will be mentioned.

After discussing normal solutions at length (pages 4–6), the author does not direct that *normality factors* be employed in calculating the results of analysis. On the contrary, he introduces the equivalent weights of various substances, and many of these equivalents are unnecessary. In giving the accuracy of ordinary pipets and burets as being within about 0.5 per cent. (page 10), he assumes a good deal of responsibility, for there is no way of judging, except by calibration, the graduation errors of any volumetric instrument. In fact, one would have to examine many pieces of apparatus in order to feel justified in making any such assertion. Hence it is unfortunate that detailed instructions are not given for testing these measuring devices. (The excellent work by V. Stott, at the National Physical Laboratory, might well have been referred to.) Directions are often given to the effect that, after dissolving the sample, the operator make the solution up to a definite volume and then take aliquot portions for the actual determinations. Though this *modus operandi* unquestionably has its advantages, it is not always feasible; especially when the constituent sought represents a small percentage only of the material that is being subjected to analysis. The apparatus depicted on page 54 (Figure 3) for use in determining the available oxygen in manganese dioxide (manganese ore) seems both antiquated and awkward in comparison with the simple, yet elegant, contrivance of F. A. Gooch and J. T. Norton, Jr. Certain of the substances recommended for use as primary standards —ferrous ammonium sulfate, oxalic acid, calcium carbonate (Iceland spar), for example—are not looked upon by the best analysts as being particularly reliable. It is surprising that any one should attempt the estimation of nitric and sulfuric acids in the presence of each other by *indirect analysis*, seeing that it is a simple problem to remove the more volatile acid by evaporation on a steam bath; whereupon the direct titration of the residual sulfuric acid is in order. The conditions laid down for the formation of ammonium manganese phosphate and ammonium magnesium phosphate, respectively, are not sufficiently definite (page 141), and the obtainment of good results, without better directions, would doubtless be somewhat a matter of chance. H. J. H. Fenton's method for the direct determination of sodium with the aid of dihydroxytartaric acid (pages 106–8) fails in the presence of much potassium, and certain other substances interfere more or less. It is regrettable that, in describing the estimation of ferric iron by means of titanous chloride (pages 100–1), the author did not mention the very interesting monograph by E. Knecht (with Eva Hibbert) on the multifarious applications of the salts of trivalent titanium in volumetric analysis; for, in this way, he would have established at least one exception to the rule: "A prophet is not without honor, save in his own country."

In contrast to the above, Berry's manual contains some unusual volumetric processes that are not to be found in the general run of analytical texts. Among these one notices with pleasure two ingenious methods that are original with the author: the determination of thallium in the thallous condition (page 99) and the estimation of Caro's acid, H_2SO_5, when in admixture with perdisulfuric acid, $H_2S_2O_8$, using vanadyl sulfate as an auxiliary reagent (page 173).

As usual, the Cambridge University Press has produced a book that is pleasing in point of appearance. And its small size should render it a very convenient adjunct to either the classroom or the laboratory.

WILLIAM M. THORNTON, JR.

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GENERAL AND INORGANIC CHEMISTRY. *P. J. Durrant*, Fellow, Tutor and Lecturer in Chemistry, Selwyn College, Cambridge. Longmans, Green and Company, New York, 1939. x + 547 pp. 14 × 22 cm. $2.75.

A description of this book should be preceded by a few words on the English secondary schools. There are five grades, or forms. Pupils in the first three forms take a standard course consisting of general science, mathematics, Latin, French, and English. A student who then elects to specialize in science devotes a large portion of his time in the fourth and fifth forms to the study of chemistry and physics. Upon completion of the fifth form, he may seek further preparation in an optional sixth form, or may enroll directly in the university.

This book is designed for students in the sixth form or in the first year of university work, and presupposes two years of secondary-school chemistry. There are probably not many American schools where it can be used as a text. It may be used, however, for selected groups of freshmen or for second-year courses in general chemistry. Every teacher of elementary chemistry could profitably use it as a reference text and teaching aid. It presents a point of view which is entirely new to American readers.

The first nine chapters (two hundred sixteen pages) are devoted to theoretical chemistry—the atomic and molecular theories, states of matter, molecular, equivalent and atomic weights, atomic structure, the periodic classification, valency, solution, velocity of reaction, law of mass action, equilibria, electrolysis, acids, bases, and salts. This portion of the book resembles our rather elementary physical chemistry texts, and is more advanced than any American freshman textbook with which the reviewer is familiar. Terms such as "molecule," "symbol," and "element" are given little or no discussion. The determination of equivalent and molecular weights is given thirty

pages. One or two bits of elementary calculus appear. Except in the treatment of the atomic and molecular theories, the historical approach has been completely abandoned—a development which greatly simplifies the teaching of such topics as valence and ionization. The modern theory of atomic structure is described, but no experimental evidence is presented for it.

The descriptive portion of the book is equally interesting. Many of the topics usually stressed in American books are given scant mention, or none at all. Iron is given seven pages, manganese, two, and chromium, three and one-half. Cobalt, nickel, strontium, and cadmium are not discussed. There is very little on hardness in water and nothing on photography. On the other hand, many topics are given more emphasis than is usual in American books. Structural formulas and electronic formulas are used freely, and coördination compounds are discussed with surprising frequency. Many compounds with which even advanced American students may not be familiar are described, as is illustrated by the following compounds of calcium: $Ca(NH_3)_6$, CaH_2, $Ca(NH_3)_2$, $[Ca(NH_3)_8]Cl_2$, $[Ca(C_2H_5OH)_4]Cl_2$, $CaO_2{\cdot}8H_2O$.

The book naturally retains an English flavor. Emphasis is put on industrial processes used in England, and occurrences of minerals of interest to the English. Intensive drying is mentioned in several places. Solid carbon dioxide is referred to as "drikold."

It is a pleasure to recommend this book by Dr. Durrant. The freshness of his point of view and the excellence of his literary style make it worthy of wide acceptance.

JOHN C. BAILAR, JR.

UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

SECOND YEAR COLLEGE CHEMISTRY. *William H. Chapin*, Oberlin College. Fourth Edition, revised by *William H. Chapin* and *Luke E. Steiner*. John Wiley and Sons, Inc., New York City, 1938. xv + 407 pp. 42 figs. 15 × 23 cm. $3.00.

This book is the fourth revision of the original which appeared in 1922. According to the preface the author's purpose in writing the book was to provide a course to bridge the gap between the general chemistry of the freshman year and the physical and inorganic chemistry of the junior and senior years. In this aim the authors of the present edition have succeeded to an unusual degree.

The importance of a knowledge of physico-chemical principle as a basis for the intelligent understanding of organic, inorganic, analytical, and colloid chemistry, both from the standpoint of methodology and in the interpretation of experimental observations, is generally recognized. Thus the title of the book might equally well have been ELEMENTARY PHYSICAL CHEMISTRY. With much of the more elementary material in the conventional course in physical chemistry relegated to such a "second-year chemistry" course, an opportunity is afforded to intensify the work of the course in physical chemistry proper, which would follow in the junior or senior year. Incidentally, it becomes an excellent companion course to any course in analytical chemistry, qualitative or quantitative, which may be prescribed for the sophomore year. In the reviewer's opinion, therefore, the book fills a definite need in the conventional sequence of the chemistry course.

The place of such a course in the chemistry curriculum is justified and made necessary by the very fact that the principles underlying both qualitative and quantitative analysis are inherently physico-chemical. We have been putting the cart before the horse. What teacher of analytical chemistry has not found it necessary to devote a considerable amount of time to a discussion of the principles of equilibrium, solubility-product, complex-ion formation, phase rule, and colloid chemistry? And would the student not be in a better position to carry out intelligently the typical quantitative procedures if he had previously mastered the principles underlying the use of indicators, hydrolysis, pH changes in neutralization reactions, coprecipitation, thermal decomposition, and electrode potentials?

The present revision involves rather extensive changes over previous editions, both in the choice of subject matter and in the method of presentation. The chapters dealing with solutions of electrolytes, X-rays and radioactivity, valence and electrochemistry have been largely re-written and a new chapter on atomic transmutations introduced. The generalized concept of acids and bases is introduced, together with the practical application of the concepts of activity, activity-coefficient, and ionic strength as applied to strong electrolytes. The reviewer is inclined to question the value of introducing into the usual equilibrium equations for neutralization and hydrolysis, the hydronium ion H_3O^+ in place of H^+. Other than to emphasize the fact that hydrogen ion is hydrated, it would seem to complicate rather than clarify the presentation for the beginning student.

The chapters on "Atomic Structure and Valence" and "Atomic Transmutations" are certainly masterpieces of exposition and may be read with considerable profit, especially if such reading is accompanied by the solution of the fascinating exercises at the end of these chapters, by the student who has had a course in physical chemistry and theoretical physics. The reviewer is led to wonder whether a second-year student who has had only the beginning course in general chemistry and may or may not have had college physics, could gain much of a working knowledge of isotopes, nuclear structure, electron distribution, and the products of nuclear bombardment by means of different projectiles. Nevertheless, the material is excellent and the extent to which it "gets across" will depend largely upon the individual lecturer.

The authors' emphasis upon problems is a feature which commends itself. That well-known dictum of Le Chancourtois: "Les propriétés des matières sont les propriétés des nombres" emphasizes the fact that unless our reasonings can be reduced to a quantitative basis, the precision of methods tested, and unknown quantities calculated, our science is, indeed, inadequate. Many new and valuable problems have been added, and others, involving calculations which are not exact enough to be useful or which the student will not find applicable to his later work, have been eliminated.

The book is strikingly free from typographical errors. It is deserving of commendation for its precise presentation of the fundamental concepts, and will therefore be valuable, not only as a textbook for class use but also for reading by those who may desire to bring their knowledge of general chemistry up-to-date.

T. F. BUEHRER

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CHEMICAL INDUSTRIES. Edited by *D. M. Newitt*. Chemical Publishing Company of New York, New York City, 1939. lxxix + 379 pp. 20.5 × 27.5 cm. $4.00.

"This book is designed to serve two purposes, firstly to provide actual facts, and secondly to give outlines for ideas from which practical plans can be formed.

"The present volume is the thirteenth edition of a publication which for nine years was known as the Chemical Engineering and Chemical Catalogue. There was no issue dated 1934 owing to the complete replanning of the whole work, and in 1935 the new CHEMICAL INDUSTRIES appeared. The sectionalized planning was apparently much liked, as the whole printing was exhausted in September of the same year.

"In earlier years we have introduced a few random tables and some data, peculiarly suitable for chemical engineers, of a nature not easily available elsewhere; some, in fact, were specially compiled for the book. The fact that this was necessary seemed to indicate that a reference book of information for those employed in the chemical-using industries was really needed. The managing editor was advised and the sections formed and filled up. At this time, also, we had ready the first section of matter on Fine Chemicals and Pharmaceuticals, which it had been intended to publish as a separate book. This was, however, incorporated in the revised CHEMICAL INDUSTRIES, and very considerably enriched its value.....

"There are two main additions to the subject matter this year. Several tables of chemical symbols and abbreviations have been added: these symbols were recently published as British Standards, and are based on a report of a Joint Committee of the Chemical Society, the Faraday Society, and the Physical Society. Last year, a dictionary of Raw Materials for the Paint and Allied Industries was introduced; this has been substantially augmented, and new products included.

"There is included an index to the whole subject-matter of the book; the improved form of 'thumb-index' to the sections has been retained, as it has proved entirely successful.

"The inclusion of a Table of Physical Constants of Inorganic and Organic Compounds, an entirely new section of new matter specially compiled for CHEMICAL INDUSTRIES, and never previously published as one, and the bringing of the indexes to the front of the book, including (1) the firms whose advertisements extend and complement the editorial information, and (2) the products made by these firms, were new features in 1937.

"A considerable amount of care has been devoted to the classification of the contents. The book is divided into ten sections, each one dealing with some particular phase of plant construction or manufacturing process. Thus, for example, Section I gives an account of the various materials used in plant construction, their mechanical and chemical properties, and data regarding methods of working and resistance to corrosion; whilst Section IV deals with size reduction and mixing and blending of solids, and outlines briefly the principles underlying these operations and their application as illustrated by well-known forms of mills and mixers. Wherever possible, quantitative relationships have been expressed in the form of simple equations or relevant tabulated data.

"Owing to limitations of space the treatment of fundamental processes such as grinding, filtering, and evaporating has necessarily had to be condensed. It is hoped, however, that the information given will be valuable in indicating the type of plant best suited to carrying out any particular operation and the important points to look for when purchasing plant. Numerous references to current literature are given in the text and a complete bibliography of technological works is also included....."

THE CHEMISTRY OF ORGANIC COMPOUNDS. *James Bryant Conant*, President of Harvard University, formerly Sheldon Emery Professor of Organic Chemistry. Revised with the assistance of *Max Tishler*, Research Chemist, Merck and Company. The Macmillan Company, New York City, 1939. Revised Edition. x + 658 pp. 14 × 21.3 cm. $4.00.

The revised edition of this excellent textbook will be welcomed by all teachers of organic chemistry. It is an up-to-date treatise which will be very useful. The authors have altered the treatment of certain subjects and condensed the space devoted to a few topics in order to make room for recent developments in organic chemistry. By this means new material on valence, resonance and energy relationships as well as the chemistry of hormones, vitamins, sugars, proteins, and other biochemical compounds have been included without making the book unbalanced or unwieldy and with an increase of only thirty-one pages of text over the earlier edition.

The general order of treatment in the first half of the book is unchanged. Basic principles are stressed, and the experimental basis of structural formulas emphasized. The alcohols are taken up first, followed by alkyl halides, esters, ethers, hydrocarbons, acids, aldehydes and ketones, polyhalogen compounds, derivatives of ammonia, and polyfunctional compounds. An idea of the general distribution of subject matter is indicated by the fact that this material constitutes about one-half of the book (three hundred nineteen pages out of six hundred twenty-five pages of actual text) and provides a sound foundation of reactions and syntheses. The chemistry of aromatic compounds is taken up next (one hundred forty-seven pages) followed by alicyclic compounds including terpenes and sterols (thirty-eight pages), heterocyclic compounds (twenty-three pages), and finally five chapters on special topics (ninety-eight pages).

Electronic formulas are used more freely than in the first edition, but only when it is sound pedogogy to do so. An excellent exposition of the concept of resonance is given in connection with the structure of guanidinium salts. The non-existence of electronic isomers, the shortened internuclear distances between atoms and energy relationships are used to give an experimental approach to an understanding of the concept of resonance only in those particular cases where it is really important and useful.

The chapters on special topics give the beginning student the essential information concerning vitamins, sterols, sex hormones, synthetic drugs, proteins, plant and animal pigments, and stereochemical topics. An excellent index is provided.

The book is designed for use in a full year's course in organic chemistry and fulfills its purpose. The textual matter is not only well written technically but the presentation is interesting and attractive to the student.

R. L. SHRINER

UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

TEXTBOOK OF ORGANIC CHEMISTRY. *E. Wertheim.* P. Blakiston's Son & Co., Inc., Philadelphia, Pennsylvania, 1939. xiv + 830 pp. 15 × 23 cm.

"This book presents material for a two-semester course in the theory of organic chemistry. It is intended to serve the needs of students who will major in chemistry or specialize in organic chemistry, also of those who are enrolled in premedical or chemical engineering courses"—from the author's Preface.

This book has much to commend it as a textbook of elementary organic chemistry. In the first place, having appeared in two previous editions (in mimeographed form) which were widely used over a period of many years, it has behind it the test of actual use. In book form the value of the work is greatly enhanced by greater readability, abundant illustrations and the more liberal use of graphic formulas, and by some expansion of the material covered. Attention may be drawn particularly to the large number of half-page portraits of leading organic chemists of the past and present. Extensive use is made of reaction charts to indicate inter-relationships of compounds and of diagrams to illustrate stereochemical points. At the end of each chapter are given review questions and a short bibliography of recent literature, the latter including for the most part only articles published in the journals of the American Chemical Society. In order to make the subject as attractive as possible to students whose interest in organic chemistry is not for its own sake frequent reference is made to the newer developments in industrial processes and products and to compounds of chiefly biological or medical interest.

The arrangement of subject matter is orthodox, that is to say, the author begins at once with the paraffin hydrocarbons and deals systematically with the common aliphatic types, thereafter with aromatic types, and finally with special types (dyes, proteins, and so forth). The only deviations from the arrangement by structural types are that the Grignard and Friedel-Crafts reactions are dealt with in a separate chapter and the subject of optical activity is discussed in a very brief chapter which serves as an introduction to the chapter on carbohydrates. Noteworthy additions to the usual subject content are the chapter on the identification of organic compounds and a lengthy, but valuable, appendix which contains among other things, industrial flow sheets, a chronological table, notes on nomenclature, and a table of physical constants.

The book is uncommonly lengthy for an introductory text. This is partly a consequence of the wider variety of reactions dealt with, and partly a consequence of the more detailed treatment of the reactions. It is almost inevitable that in treating these reactions in more detail than usual the book should occasionally rise above the elementary level. Thus, for example, in connection with the formation of primary amines by the Hofmann degradation of amides it is pointed out (footnote, page 291), for

the first time in an elementary textbook so far as the reviewer's knowledge goes, that the reaction is limited to the amides of acids having less than five carbon atoms. So also it is indicated (page 296) that the reaction of nitrous acid with aliphatic primary amines, as a method of replacing an amino group by a hydroxyl group, is subject to certain limitations. The amount of material presented is, in fact, greater than could normally be covered in a two-semester course, especially since the instructor using this textbook will probably find it desirable to amplify very considerably the somewhat sketchy and disconnected treatment of the theoretical aspects of the subject. However, in the matter of choosing between too much and too little factual content the author has wisely elected to err in the direction of too much, and the final discretion is properly left with the individual instructor.

WELDON G. BROWN

THE UNIVERSITY OF CHICAGO
CHICAGO, ILLINOIS

USES AND APPLICATIONS OF CHEMICAL AND RELATED MATERIALS. *Thomas C. Gregory.* Reinhold Publishing Corporation, New York City, 1939. vi + 665 pp. 14.5 × 23 cm. $10.00.

"Since 1922 there have been appearing in the pages of *Oil, Paint and Drug Reporter* a series of surveys covering the uses, potential applications, and sales possibilities of chemicals and related raw materials.

"At first these surveys appeared under the title 'Where You Can Sell.' Subsequently the title was changed to 'Industrial Uses of Chemicals and Related Materials.'

"The early research was conducted by the late Ismar Ginsburg; and since his death in 1933 has been continued and expanded by Thomas C. Gregory, one of the editors of THE CONDENSED CHEMICAL DICTIONARY and a nationally known expert on chemical marketing.

"Recognizing the great permanent value of this information, an arrangement was effected between the publishers of *Oil, Paint and Drug Reporter* and Reinhold Publishing Corporation whereby the material could be made available in book form after rearrangement, amplication, and complete editing by Mr. Gregory.

"In its present form it makes available to sales executives, research directors, manufacturers, dealers, and all others interested in the uses of chemical products, a mass of information unavailable elsewhere and of tremendous practical value."

PHOTOCHEMISTRY AND THE MECHANISM OF CHEMICAL REACTIONS. *Gerhard K. Rollefson,* Ph.D., Associate Professor of Chemistry, University of California, and *Milton Burton,* Ph.D., Instructor in Chemistry, New York University. Prentice-Hall, Inc., New York, 1939. xiv + 445 pp. 59 figs. 15 × 23 cm. $5.75.

There has been for some time a dearth of texts on photochemistry written in English. In the ten or eleven years since Kistiakowsky wrote his monograph and Griffith and McKeown wrote their textbook a great deal has been accomplished, and most of this new material has been effectively inaccessible to students.

The volume under review has been admirably designed to fill this gap. It is to a high degree self-contained. If any ideas are needed as a background to the understanding of photochemical problems, they are presented in logical and succinct form. The wide range of topics covered is indicated by the chapter titles, The Quantum Theory of Spectra, Photoactivation and the Properties of Photoactivated Molecules: I. Physical Effects, and II. Chemical Effects, Reaction Kinetics, Photolysis in the Solid State, Photolysis of Vapors of Inorganic Compounds, Photolysis of Vapors of Carbon Compounds, Molecular Rearrangements, Photosensitization, Typical Chain Reactions, Addition Reactions and Associated Phenomena, Polymerization, Effects in the Liquid State, and Heterogeneous Reactions. This last chapter includes discussions on photographic processes and photosynthesis.

The authors appear to have been unusually successful in finding a suitable compromise between the detailed treatment expected in a treatise and the clear-cut outlines necessary in a textbook. They have accomplished this by careful selection of the material included, by focussing attention on the present status of each problem, and by packing a large amount of valuable information into tables and graphs. The appendices add to the practical utility of the book; they include a table comparing the various notations for atomic energy states, tables of heats of reaction and bond strengths, a table of activation energies of simple reactions, and a chart for converting energy units.

One feature worthy of special commendation is the treatment of photochemistry as a living, growing subject. No attempt has been made to cover up the seamy side. "When doubt has been felt, it has been expressed. Throughout the book there have been emphasized not only the questions which photochemistry has answered but also the questions to which it must still provide an answer." And to be convinced that there are still some unanswered questions, one need only glance at the discussion of the reaction between hydrogen and oxygen.

The book is attractively bound and printed. In recommending it very highly the reviewer hopes that it may serve to stimulate additional interest in the complicated and fundamental problems of reaction mechanisms and photochemistry.

E. J. ROSENBAUM

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SELECTIVE EXPERIMENTS IN GENERAL CHEMISTRY. *Alexander Silverman,* Sc.D., Head of the Department of Chemistry, University of Pittsburgh, and *Abraham L. Robinson,* Ph.D., Assistant Professor of Chemistry, University of Pittsburgh. D. Van Nostrand, New York City, 1939. ix + 309 pp. 39 figs. 25 × 28 cm. $2.50.

These SELECTIVE EXPERIMENTS are designed to accompany the freshman college course in general chemistry. In addition to the experiments found in the usual manual the following are included: The Quantitative Determination of Ba as $BaSO_4$, Determination of O_2 in Air by Pyragallol, Determination of the Freezing Point of Solutions, Quantitative Determination of NH_3 in Ammonium Salts, Conductometric Titration, Faraday's Law by Electrolysis of Copper Sulfate, Rate of Hydrolysis of Acetamid, Oxidation Reduction Titration, Electrolytic Preparation of Chlorates and Hypochlorites, Contact Process for Sulfuric Acid Using V_2O_5 as a Catalyst, Preparation of Guncotton, Preparation of Ethyl Alcohol, Reactions of V, Mo, W, and U. The material on the metallic elements is arranged according to periodic grouping with the exception of Al, Sn, and Sb, and these are placed together. Qualitative analysis is not considered, although qualitative tests are given under the respective elements. The number of quantitative experiments is well above that of the average manual, and several require the recording of electrometric data.

A group of exercises is placed at the end of each experiment. About half of the pages of the book are report sheets where space is provided for a complete write up of the experiment.

A loose-leaf binding is used, and undoubtedly many of the pages will tear loose in actual use. Including the report sheets in the same volume as the descriptive material subjects them to laboratory hazards, and many of these must be in a soiled condition before the completion of the course. This also makes the book larger and more cumbersome than is warranted by the printed material.

The number of experiments is sufficient so that the instructor may choose those best suited for the class. The manual is thus designed for both beginners and students who have had chemistry in high school.

The directions are clear and the entire book is well written. Illustrations are plentiful, and the student should find no difficulty in arranging his apparatus and carrying out the experiments.

C. E. WHITE

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COLLEGE PARK, MARYLAND

JAROSLAV HEYROVSKÝ (1890–)

Born in 1890 in Prague, the son of a professor of Roman jurisprudence at the Czech Charles University, Jaroslav Heyrovský received his early training and secondary education in his native city. After one year of study at the Czech University of Prague he spent five years (from 1909–1914) at the University of London. During the World War he served in the infantry of the Austrian army. On his return to the university he was awarded a Ph.D. degree in 1918 and two years later the University of London gave him a D.Sc. degree. He entered upon his academic career in 1919 when he was appointed instructor in chemistry under his former teacher, Bohuslav Brauner. His advancement in the faculty of sciences of his alma mater was rapid. Starting as privat-dozent of physical chemistry in 1920, he was made extraordinary professor in 1922 and four years later professor of chemistry and director of the Institute for Physical Chemistry, where he has since made a reputation for himself and his many pupils and collaborators. Along with his many-sided activities in the field of education he has been able, in the past twenty years, to carry out a remarkable series of investigations with the dropping mercury electrode. This arrangement is a modification of Lippmann's capillary electrometer which was changed by a Czech scientist, Kučera, into a dropping capillary for a more detailed study of the surface tension of the polarized mercury.

In 1922 Heyrovský succeeded in using the Kučera outfit for a comprehensive study of current-potential phenomena from which resulted (in 1925) the automatic recording device, now universally known as the polarograph.

Although Professor Heyrovský spent some time, in 1933, in California as visiting professor at the University of California and the California Institute of Technology, the response of American science and industry to his polarographic method has been rather slow, and it is only in the past two years that important contributions from American investigators (Adkins, Karsten, Müller, Daniels, Kolthoff, Lingane, and others) have appeared in the chemical literature. In this connection it is of interest to recall the symposium on polarographic methods at the 1939 Spring meeting of the American Chemical Society and the excellent résumé of the subject in *Chemical Reviews* early in the same year. In addition to Heyrovský's own "polarograph" and the recently introduced "micropolarograph" there are now two American-made types of instruments (elecdropode and electrochemograph) on the market. At least two laboratory manuals have been published in German, but so far no English text on polarographic practice has appeared in print.

Those of us who have met him, either in this country or abroad, will remember his pleasant, modest personality and admire his devotion to the branch of science which he has so notably enriched. Faraday's motto, "Work, finish, publish," which greets the visitors in his Prague laboratory, is no idle slogan for Heyrovský and it is fitting that we add to our congratulations on the successful attainment of the half-century milestone, the wish that we have "more light" from Prague in the solution of many pressing problems. Heyrovský's published work contains well over one hundred publications which have appeared in various journals, mainly, however, in the well-known "Collection" which he founded in 1929 in collaboration with E. Votoček.

Recognition of his outstanding contributions to chemistry has come from far and near. He is a member of the Royal Bohemian Academy of Science and of the Czech Scientific Research Council, an honorary member of the American Academy of Science and Art and of the Austrian Chemical Society and a Fellow of London University College. The California Chapter of Sigma Xi honored him with full membership, and quite recently he was awarded the gold medal of the University of Nancy in France.

(*H. S. Van Klooster, Rensselaer Polytechnic Institute*)

EDITOR'S OUTLOOK

PATIENT INTELLIGENCE. Educators with a background of training in the dead languages, the so-called classics and humanities, and the gaudier pseudo-sciences often display an annoying (not to say alarming) ineptitude to grasp the philosophy and aims of the true sciences, and, consequently, an extremely meager appreciation of the proper rôle of scientific instruction in a liberal education. From time to time Huxley must stir uneasily in his grave.

Yet we may well pause and ask ourselves if we have not contributed to the attitude we deplore. It may be that some of these gentlemen have passed lightly over the professions of faith of the scientific idealists, and have based their opinions on our actual works. Many a university president, if he ever takes the trouble to glance over that section of the copy for his annual report which lists the publications of the scientific departments of his institution, has some reason to suspect that science is too much preoccupied with the uninspired, unimaginative accumulation of new, but more or less trivial, facts.

Why is this so? To deal more specifically with the branch of science most familiar to the writer, why have there been so few major contributions to the fundamental theory of organic chemistry since the establishment of the structural theory? Why have most of the significant contributions to organochemical theory in the past decade been made, not by organic chemists, but by physical chemists and physicists? Why is so great a proportion of organochemical literature today devoted to the description of the preparation of compounds and the recording of their physical properties?

One reason that suggests itself is the way in which the admirable emphasis of the universities upon "productive scholarship" has worked out in practice. It was once remarked that universities rate their professors like artillery—upon the basis of poundage emitted. Today it is nearly as true to say that they rate them upon the number of published titles per annum. Even when a man has conceived and executed a well-rounded and well-integrated program of research, the temptation to publish it piecemeal is very strong. Editors and referees have increased the pressure. It is an editorial axiom that a thirty-page manuscript must be shortened, even though it be so well and economically written that condensation is impossible. Feed the same editor the same material in six easy installments of approximately seven pages each, and the chances are he'll swallow it without a murmur.

Under our present system much of a professor's research is performed by his graduate students. It takes a lot of planning in advance, constant supervision, and occasional revision of program to make sure that a student started on a fundamental piece of research will progress far enough to acquire his degree in a reasonable time. Put him to work preparing a series of derivatives and determining their physical constants, and if he is worth his salt everything works out automatically.

Fundamental research is uncertain, time-consuming, and demanding. Preparative and accumulative research may be placed much more nearly upon a mass-production basis.

Many of the older chemists are temperamentally incapable of change, and some of them are intellectually incapable of anything more than fact-collecting. To some of the younger chemists, however, we would recall the familiar plea for "patient money" in industrial research. Rewards (though not necessarily monetary ones) also await patient intelligence. The "system," if one wants to call it that, undeniably exerts pressure, but it can be beaten.

GEORGES URBAIN[1]

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AND

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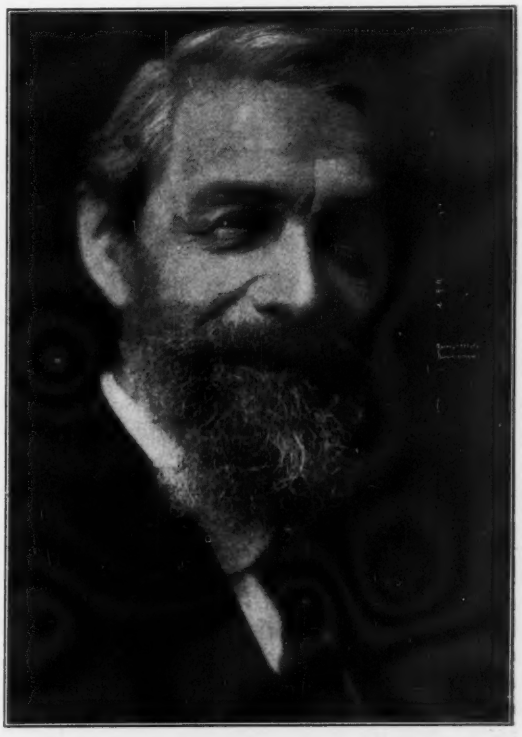
SCIENCE has lost one of its most illustrious figures in the death of Georges Urbain, Member of the Institute of France, Professor at the University of Paris, Director of the Institute of Chemistry of Paris. It was the privilege of one of us (C. H. Boatner) to work with him too short a time, one year at the Institut de Biologie Physico-Chimique; to the other of us (G. Champetier) was accorded the greater privilege of a longer association extending over a period of ten years, first at the Institut de Biologie Physico-Chimique and later at the Institut de Chimie. We welcome this opportunity to bring to American chemists an appreciation of the life and work of this great man.

Georges Urbain was born in Paris in 1872. His father, Victor Urbain, was an assistant to Frémy and professor at the Ecole Supérieure Lavoisier. He occupied his spare moments in drawing. Georges Urbain thus developed in a home which provided him with a scientific training and a taste for art. Following his father's wishes, Georges Urbain entered the Ecole de Physique et de Chimie de Paris, from which he graduated first in his class in 1894. His short term as assistant in the laboratory of mineral chemistry of this school brought him in contact with Pierre Curie. It was Pierre Curie who revealed to Georges Urbain the beauty and the greatness of scientific discovery. From this moment his course was determined, and a friendship both personal and scientific was begun which was to endure a lifetime. With his characteristic ardor Georges Urbain consecrated himself from this moment to research.

He then entered the laboratory of Charles Friedel as instructor and there confirmed his ability in research. He was named Assistant Professor of Analytical Chemistry in 1906, Professor of Mineral Chemistry in 1908, and Professor of General Chemistry, Director of the Institut de Chimie de Paris, and Co-Director of the Institut de Biologie Physico-Chimique in 1928.

He had soon built the Institut into the mecca of all good chemistry students in France. The young student who was able to get into the Institut took it as a mark of his superiority and furthermore felt assured that he would be prepared at the end of his courses there to take his place in his chosen field of chemistry whether it be teaching, industrial chemistry, or research. At the same time M. Urbain, first as Professor of Mineral Chemistry, and then as Professor of General Chemistry at the Sorbonne, was conducting a brilliant series of lectures. These courses were not only superior intellectual and pedagogical efforts, but they were immensely popular with the students with whom his courses had the reputation of being not only



Courtesy of Dr. R. E. Oesper

GEORGES URBAIN

[1] Presented before the Division of History of Chemistry at the ninety-seventh meeting of the A. C. S., Baltimore, Md., April 5, 1939.

good, but interesting. In 1930, anyone who did not go early to his lectures in general chemistry was fortunate if he found a seat in the gallery of the large amphitheater. M. Urbain's popularity with the students was impressive in view of the fact that obtaining a certificate in general chemistry, for which M. Urbain's course was required, was considered extremely difficult. The students rose in a body when he entered the room, they listened with such complete attention that there was not a murmur to be heard in the class of three hundred fifty students. The attention of the students bordered on perfection, but it was seldom that the perfect silence was maintained for a full hour. It rarely happened that at least once in every hour M. Urbain did not so beautifully demonstrate some important

MEDAL STRUCK IN COMMEMORATION OF THE SCIENTIFIC JUBILEE HELD IN HONOR OF GEORGES URBAIN IN PARIS IN 1938

point, or let drop some so irresistibly facetious but always appropriate remark that a spontaneous burst of applause rose from the students. In 1928 M. Urbain was appointed Director of the Chemical Service of the Institut de Biologie Physico-Chimique. There he had his own research laboratory, as well as other laboratories in which chemical research was carried on under his direction or inspiration. Here, as in his research laboratories at the Sorbonne the daily appearance of "le patron" was the most important event of the day. An inspiring teacher, he knew how to communicate to his collaborators his faith in science, but above all he was to his students "le patron" who advised, who encouraged, who helped overcome difficult moments, who furnished moral and sometimes material support. His personal laboratory at the Institut de Biologie Physico-Chimique had become the center of constantly renewed discussions in which scientists of all fields in the Institut participated. Those who profited by these conversations and acquired through them a taste for general ideas are indeed numerous. Among his many students may be listed: P. Job, Professor at the University of Paris; Tourneux, Dean of the Faculty of Besançon; Chauvenet, Director of the Institute of Chemistry of Caen; Bourion, Honorary Professor at the University of Nancy; Dhar, Rector of the University of Hallahabad (India); Heyrovský, Professor at the University of Prague; Lortie, Professor at the University of Montreal; and Sarfaar, Professor at the University of Calcutta.

In addition to his artistic talents and tastes, Urbain had a deeply philosophic turn of mind. The study of the history of science fascinated him; he loved nothing better than to follow the development of ideas, or to watch the conflict of the "positive" and the "speculative." In the lectures given by him in a series entitled *Orientation actuelle des sciences* in 1930 one gets the impression of a philosopher reveling in large general ideas and theories; one sees revealed again his passion for speculation. He tells us in this lecture that in his youth he was even more devoted to speculation. And yet he chose the rare earths as his field of research. Of all possible lines open to him at the time, this was the most purely technical. After twenty thousand recrystallizations, one might hope to develop one law of small scope. This choice of a research problem, in view of his talents and his tastes, is one of the most remarkable examples of complete self-discipline that one could find. But, he tells us, "If imagination is necessary in science, more perhaps than any place else, it is no less necessary to discipline it." In fact, his whole bearing, his whole personality, his whole behavior were expressions of a man of force, intelligence, and deep sensibilities and yet of a man completely master of himself.

The fine spirit of the man is shown in these sentences taken from a report of his work on the rare earths, presented on the occasion of the dedication of the Sterling Chemical Laboratory. He deplores the fact that there were so few chemists engaged in research on the rare earths at the time he undertook his study of them, and this, he says, ". . . despite the attraction of the veritable unknown." His was a scientific curiosity of the highest order. This unquenchable thirst for truth led him at the age of twenty-three into a field in which the greatest chemists had become badly confused. His perseverance and self-discipline kept him working at a research program which covered a period of twenty-five years, and which included a number of fractionations in excess of two hundred thousand. The results of this

work are of tremendous importance. He was able to completely clear up the confusion existing in the chemistry of the yttrium series of the rare earths by effecting the rigorous separation of samarium, europium, gadolinium, terbium, dysprosium, and holmium, and finally the scission of Marignac's ytterbium into ytterbium and lutecium, a previously unknown element. In this work he reduced the number of the first members of the yttrium group from twenty possibilities to four actually isolated elements. His determinations of the atomic weights of all of these elements were accepted by the International Committee on Atomic Weights and led to his membership on that committee of which he was later president. Later, in 1911, he recognized the presence of still another element, celtium, not of the rare earth family. This element was thought by Moseley to be the missing element number 72, but upon investigation, the X-ray evidence was found to be inconclusive. Finally in 1922, after a long interruption due to work in the war, M. Urbain again took up his work with the rare earths, and submitted the suspected sample to Dauvillier for examination by means of de Broglie's improved X-ray method. This indicated the presence of element number 72. The element was isolated in larger concentrations by von Hevesy and Coster in 1922. Although the name by which they called it, hafnium, is the one most often employed, the International Committee on Atomic Weights has accepted two names, celtium and hafnium, and two symbols Ct and Hf.

M. Urbain did a great deal toward the improvement of experimental procedures for the separation of rare earths by adding the ethyl sulfates as derivatives which lend themselves more readily to fractionation and by introducing the use of bismuth salts as agents of separation of two adjacent rare earths. As the result of his work, he could announce the Law of Seriation of Rare Earths: all salts of rare earths fall in the same order of solubility, except the ethyl sulfates and the nitrates. He used the phosphorescent spectra and the coefficients of magnetism of the rare earths as means of following their separation. M. Urbain's work was not merely manual, nor was his contribution only to the technic of separation. He was the first to emphasize the importance of following the separations by both physical and chemical means, and he recognized the limits of purification which necessitate the use of several procedures for complete fractionation.

M. Urbain disliked excessive specialization. He describes the situation of a specialist in a most amusing way.[2] "The specialist works in a pit. The details of his specialty absorb him to the point where he thinks he is making science, but most often he is making only erudition. He has a mania for document and leaves to others the task of coördinating that which he collects and with which he encumbers his special publications." Although M. Urbain, himself, might be thought to have specialized excessively, since he was engaged almost solely in research on the rare earths for a period of twenty-five years (at that, the rare earths represent one-sixth of the known elements), this specialization is only apparent and not real. We note that he took time to do extensive work on absorption spectra, emission spectra, and phosphorescence spectra. His contributions to the study of cathodic phosphorescence spectra were of particular importance. He perfected the technic of phosphorescent spectra, finally created order from chaos, and announced the laws governing this extremely complex phenomenon.

SCENE IN THE LABORATOIRE DE CHIMIE GENERALE OF THE SORBONNE. SEATED LEFT TO RIGHT: M. JEAN PERRIN, MME. RAMART-LUCAS, M. GEORGES URBAIN. (THE AUTHORS ARE STANDING NEXT TO M. URBAIN)

One might think that those numerous jobs, Director of the Institute of Chemistry, Professor of Mineral Chemistry, and then Professor of General Chemistry, Director of the Chemical Service at the Institut de Biologie Physico-Chimique, President of the Société de Chimie, member of the International Committee on Atomic Weights, during the war from 1914 Director of the Chemical Laboratory of the Technical Section of the Artillery, in 1916 member of Inspection des Etudes et Expériences Chimiques de Guerre, then at the death of Charles Moureu, President of the Comité Scientifique des Poudres et Explosifs and of the Commission des Substances Explosives, along with his time-consuming research on the rare earths and spectro-chemistry would have left him little spare time; yet M. Urbain found time to write four excellent texts: "Introduction à l'étude de la spectro-chimie" (1911), "Introduction à la chimie des complexes"—Urbain et A. Sénéchal (1913), "L'énergétique des réactions chimiques" (1925), "Traité de chimie générale"—G. Urbain, P. Job, G. Allard, et G. Champetier (1939).

The "Introduction à l'étude de la spectro-chimie" does not pretend to be an exhaustive treatise on spectro-chemistry. It is presented as an introduction to young chemists of the methods of spectral analysis, but it does

[2] "Les disciplines d'une science. La chimie," p. 30.

include some new methods, particularly for phosphorescence spectra. As usual, M. Urbain has included a careful historical survey of the subject. The theoretical matter is clearly presented and is accompanied in each chapter with explicit practical instructions. In this book, M. Urbain presents the method of spectral analysis by means of visual comparison of the spectrum of the unknown metal with that of iron as a standard. This method has obvious advantages for the chemist over the method of identifying each line by direct measurement. In an accompanying elaborate series of charts of the emission spectra of iron and of a large number of other metals he presents the means of applying this excellent method of identification of elements by spectral analysis. M. Urbain's interest in this visual comparison method of spectral analysis led to the publication by a student and collaborator[3] of an excellent and elaborate series of plates of the arc spectra of a great many elements, including iron, with intensities and wave-lengths indicated.

The "Introduction à la chimie des complexes" of G. Urbain and A. Sénéchal is an exhaustive treatise of four hundred sixty-eight pages. It is based in part on a course developed over a period of years by M. Urbain at the Sorbonne. When it was rewritten for publication, a preliminary introduction of the fundamental relations of inorganic chemistry was added. This is a particularly clear and thorough presentation of the basic concepts of physical and inorganic chemistry. The second part of the book is a critical exposition of Werner's theory of complexes, and the third part is a monograph on the complexes of platinum, cobalt, copper, and chromium with extensive bibliographies. This book should make a superb basic text for an advanced course in inorganic chemistry, and it should prove of value to any chemist interested in the field. It is not only an annotated bibliography and compilation of the work of others; it represents the results of the personal experience of the authors, of their experimental research, of their reflections and meditations in the laboratory, and of their scientific publications in the field of complex compounds. Georges Urbain and his school have made important theoretical and experimental contributions to the chemistry of complexes.

M. Urbain's third text, "L'énergétique des réactions chimiques," published in 1925, is a theoretical introduction to the energetics of chemical reactions. This, too, is based on a course given by M. Urbain at the Sorbonne for several years. As the author writes, he recognized the need of chemists of a relatively complete treatise on chemical thermodynamics written not from the point of view of a physicist or of a mathematician, but from the point of view of a chemist. As a pure chemist, from his own experience in mastering the subject, he could recognize the points difficult for chemists to grasp which neither physicists nor mathematicians would deign to emphasize. He has stressed the functions of state of greatest chemical importance, he has avoided overstressing mechanics, and he has used significant chemical illustrations wherever possible. The achievement of the book is that it is easy for the "atomistically" trained chemist to understand, and yet it has remained true to the spirit of thermodynamics.

Georges Urbain's last text, "Traité de chimie générale," written with P. Job, G. Allard, and G. Champetier, was published after his death. The major part of this book is the work of Georges Urbain. It represents his course in general chemistry at the Sorbonne in the state of near perfection to which he had developed it by constant improvement and constant change in order to keep it completely up-to-date over the period of thirty years during which he lectured on the subject of general chemistry. In this book, as in all of his texts, Georges Urbain writes not only an excellent textbook on general chemistry but he includes much of a fundamental philosophical nature, and a tremendous amount of historical material since he feels, as he tells us in the introduction, that general chemistry by its very nature signifies chemical philosophy.

And yet, Professor Urbain says, "The greatest scientists are those who have given science new methods of thinking; the others are merely good workers." Georges Urbain was not merely a good worker. As he remarks, somewhat ironically, during the years of his slow and tedious separation of the rare earths he had a great deal of time for reflection. The concentrated fruits of his reflection are published in three purely theoretical treatises: "Les disciplines d'une science. La chimie"; "Les notions fondamentales d'élément chimique et d'atome"; "La coördination des atomes dans la molécule. La symbolique chimique."

It would be difficult to estimate the value of M. Urbain's contributions to theoretical chemistry. He developed specifically the concept of homeomerism and contributed to the extension of the coördination theory of Werner. The concept of homeomerism can be explained as follows, more or less in Urbain's own words. Although by isomorphism most chemists understand syncrystallization, isomorphism is really a broader relation. Isomorphic compounds are those with identical energy coefficients, such as coefficients of magnetism and coefficients of thermal expansion. The concept of isomorphism is extremely interesting, but it is limited to the crystalline state. M. Urbain proposes a concept which would include all possible states of matter by dropping only the condition of equality of interfacial angles; he calls this concept homeomerism. Thus two substances are homeomeric when they have equal molecular coefficients of energy. As he points out, the usefulness of this concept lies in the fact that the quantities with which it is concerned are actually measurable. This can lead, among other things, to a rigorous definition of isotopes as elements which are rigorously, or almost rigorously, homeomeric. In this way one can take into account the equality of the properties of isotopes which are measurable in terms of energy, and one can explain their identical chemical behavior.

[3] "Atlas de Spectres d'Arc," Jacques Bardet, Doin, 1926.

Deeply interested in philosophy, Urbain was also a student of the history of the development of chemistry. His book, "Les disciplines d'une science. La chimie," is, in the opinion of Paul Job, a magnificent monument of chemical philosophy which can be compared only to the immortal lessons of Jean-Baptiste Dumas. He could, moreover, just as keenly analyze the development of contemporary science. He could search out the fallacies and inconsistencies in our present views. His last book on the coördination of atoms in the molecule and chemical symbolism is a challenging book which would interest particularly an organic chemist. It disturbs the complacency with which most of us now accept, without much thought, such well-established concepts as the quadrivalence of carbon and the double bond. In his introduction to chemical thermodynamics he remarks that although the partisans of thermodynamics as the perfect science claim that it is free of assumptions, he has found, after careful consideration, that at least a half-dozen postulates and axioms have crept into the science, and, he remarks facetiously, he is sure that he has missed a few.

As Professor Urbain's knowledge of the whole field of chemistry broadened, he became more and more impressed with the lack of unity in the ideas of chemistry in its various fields. In "Les disciplines d'une science. La chimie" an attempt at coördination of inorganic and organic chemistry leads him to the idea that the fundamental difference in the two is that in the former we are dealing with equilibrium conditions, whereas in the latter we are dealing mainly with metastable conditions which he conceives as due to a "chemical restraint." We may say that a substance is in a state of chemical restraint when a dissociation which is possible is nevertheless not produced. Later, as he restudies the situation in "La coördination des atomes dans la molécule. La symbolique chimique," he cannot believe that there is enough fundamental difference between organic and inorganic reactions, between organic and inorganic molecules, to justify the vastly different treatment of them which is the current practice. The importance of unity cannot be too greatly stressed, and its realization should be possible, particularly if some of the useless hangovers from discredited theories could be discarded from each field. M. Urbain has gone far in ferreting out a large number of these hangovers and in pointing a way toward the unification of chemistry by means of a modification and extension of Werner's coördination theory.

No discussion of Georges Urbain could pretend to be complete without some mention of his attainments in the arts. His father, Victor Urbain, communicated to him his taste for the arts. It would appear that this taste was always supreme in Georges Urbain, and that he undertook science only at the insistence of his father. He always regretted his choice somewhat, and believed that his life would have been more beautiful, if not more glorious, had he consecrated himself to sculpture or even to music which always gave him the greatest spiritual satisfaction.

Georges Urbain was a born musician.[4] Endowed with an exquisite sensibility, he found in music not only repose from his prodigious intellectual activity but the realization of noble aspirations and sometimes consolation and hope.

He played the piano from childhood, but soon abandoned formal lessons, finding them monotonous and preferring to play as he pleased. However, he was a serious student of music and studied its evolution attentively. Having read most of the didactic works on music and having assimilated the classics, he found the compositions of Johann-Sebastian Bach the most satisfying to his intellect. Richard Wagner and César Franck exercised a strong influence on his artistic orientation. Later, the rare harmonies of Claude Debussy enchanted him.

Courtesy of Dr. Tenney L. Davis

CENTENARY PLAQUETTE OF PAUL SCHUTZENBERGER WHICH WAS DESIGNED BY GEORGES URBAIN. IT WAS USED IN CONNECTION WITH THE SCHUTZENBERGER CELEBRATION AT PARIS IN DECEMBER, 1929

Georges Urbain's book, "Le Tombeau d'Aristoxène. Essai sur la musique," published in 1924, is an exposition of the thesis proposed by him that music is more intellectual than sensuous, that we find certain sounds disagreeable not simply because they are false and displeasing to the senses, but because they are not com-

[4] This account of Georges Urbain's contribution to music is taken largely from a memoir, "Georges Urbain, Compositeur," by Henry Mesmin.

prehensible to the intelligence. On this basis music can be the object, if not of a true scientific study, at least of a methodical study; and he makes a two hundred thirty-four page analysis of music and of its development in order to sustain this thesis. As Claude Seymart[5] points out, what makes the interest of this study is that the scientific proof presented by the author is given in a clear and truly elegant style. It is not one of those heavy volumes of weighty and tedious demonstrations but a suggestive essay presenting original and interesting ideas.

The musician, Georges Urbain, could not long remain contented with a philosophy. He created. He wrote in 1921 his first important compositions: "A la veillée" and two melodies on the poetry of Verlaine, "Chanson d'Automne" and "Sur l'herbe"; and in 1922, the "Magagnose and Dyonisos" theme in six brilliant variations.

He then freed himself of the Franckist school; he sought movement, atmosphere, imagery. But the artist was not satisfied, he found his writing too dense; he needed air and space, so he had to use a large and rather elaborate counterpoint. In this period he wrote several suites for the piano and several pieces of a grave and rich character for the organ. In a later period he purified his lines and composed pieces of a greater simplicity. These pieces composed in the period 1928–1932 represented the full flowering of his talent. Finally in the last years of his life he went back to his original compositions, retouching them, seeking perfection.

Thus we see that Georges Urbain was not a mere dilettante, that he contributed something of real value to music just as he contributed much of real value to science. His is probably one of the very few scientific jubilees for which the compositions of the scientist being feted could serve as the musical background of the program.

In addition to his talents as a pianist, composer, and musicographer Georges Urbain was a gifted painter and sculptor, gifts which were served by an astonishing visual memory and a rare manual dexterity.[6]

His paintings were almost exclusively landscapes, particularly between 1900 and 1914, a period during which he sought in a variety of processes the means of rendering the various aspects of forest and sea. Strongly influenced by the impressionist school he first used the technic of pointillism, which he later abandoned for the palette knife, preferring to work in thicknesses and large surfaces. From this period date some good canvasses executed in the forest of Sénart, at Saint-Cast, and at Veulesles-Roses. After 1910 frequent sojourns at Barbizon induced him to modify his manner once more. He returned to the brush and sought to utilize all of its resources; he strove, as his father Victor Urbain had done, to arrive at effects of delicacy by using transparent strokes obtained by means of highly diluted colors. This technic, which approaches the effect of water color, was to be his to the end of his life. He has left interesting sketches executed in the forest of Fontainebleau, in Portugal, in Corsica, in Algeria, and in Morocco. His last were executed in Provence, during the summer of 1938, during the months of short happiness which preceded his brutal death.

His friends usually preferred his sculpture to his painting. They did not remember all that he risked in portraiture, palette in hand. He took his revenge with clay and chisel. His first striking work was a bust of his father whose serene wisdom and kindness he rendered in a masterly fashion. From the same epoch dates a bust of his master, Friedel, which is now in the Secretariat of the Faculty of Sciences of Paris, and a bust of his life-long friend, Jean Perrin, full of youthful enthusiasm. Both are treated with boldness and without hesitancy. Later, Georges Urbain became attached, in sculpture as in painting, to a more minute technic, and he turned to the medal; we have from him portraits of eminent savants and doctors who were his masters or his friends: Paul Schutzenberger, Georges Stodel, René Wurmser, Paul Langevin. His last work was a portrait of Doctor Henri Minet, which he had time to finish and to give to the molder; his premature death deprived him of the pleasure of seeing this medal reduced and struck.

The ability, the gifts, the accomplishments of such a man leave one overwhelmed with admiration. Endowed with a high culture, philosopher, encyclopedist, Georges Urbain formed several generations of chemists. With him disappeared a great figure in French science.

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[5] Seymart, "G. Urbain: Le Tombeau d'Aristoxène," *La Revue Musicale*, **79**, 179–80 (1924–1925).

[6] This account of Georges Urbain's artistic achievements is a translation of a memoir, "Georges Urbain, Peintre et Sculpteur," by Pierre Urbain, his son.

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SOME RECENT ADVANCES *in* COLLOIDS[1]

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EVERY student, every industrialist, every biologist has had occasion to reflect upon the fact that classical physics, classical chemistry, and even the most modern physics of nucleus and quantum lie somewhat remote from everyday observations and experience. The cause lies in the fact that practically all the matter with which we commonly deal is in the colloidal condition and here the unit is not the separate atom, or even chemical molecule, but the much larger colloidal particle. The colloidal particle is the brick from which larger structures are made and if we cannot see the architecture of a house in the pile of bricks dumped on the site, still less can we infer it from the clay of which the bricks were originally made. The colloidal particle is often highly organized within itself and yet its external behavior is often as dependent upon the material that coats its surface as in the appearance of a house upon its coat of paint or stucco. This stabilizing material on the colloid particle may determine the behavior of the particle even when its actual amount is as small a fraction of the particle as the weight of paint is to that of the house.

Now it used to be taken for granted that the arrangement and behavior of these common materials of industry and life would be so complicated as to be largely a matter of empirical experience, greatly depending upon every vicissitude of their previous treatment and history.

To me the most important development of recent years has been the ever-increasing demonstration that colloids are subject to law and order and that the behavior of a colloidal particle is predictable once we know its composition and organization and most especially the nature of the stabilizing agent on its surface. Some of the most interesting colloids are those which provide their own stabilizing agents by virtue of the chemical groupings which they expose upon their surface. For example, if you wish to create a soap-like detergent all you need is to provide a polar structure capable of organizing itself into colloidal particles by putting, let us say, all the insoluble hydrocarbon portions side by side and end to end, leaving exposed a water-soluble polar group such as the carboxylate of the old fashioned soap or the sulfate or sulfonate of the newer synthetic detergents of which thousands have now been patented. Or still better, we may create a long chain by polymerization of some simple substance like ethylene oxide into long parallel chains, with just enough oxide groups on the surface to keep the particle soluble, and with almost any kind of a strong polar group on the end to make it into a superlative detergent, even though it is no longer a salt or an electrolyte and is no longer affected by hard water or acids, and so forth, like its soapy ancestors.

The soap-like substances introduce us to the enormous class of materials that form colloidal electrolytes. These include all the dyes, the protein salts, the gums, and most of the biocolloids. They have two outstanding properties expressed by the name colloidal electrolytes. They possess dissociable or electrolytic groups which may be paired off with any other ions as desired, and they have so pronounced a tendency to associate into stable colloidal particles that the usual theories of electrolytic behavior are completely submerged.

One surprising property of many of these detergents has lain buried as far as many of us are concerned in the pharmaceutical and technical literature of the last century and has only within the last few years been brought to light and carefully established by English and American investigators. The property is that dilute solutions of detergents in water can actually dissolve very

[1] Presented before the Pacific Division of the American Association for the Advancement of Science, Stanford University, Stanford University, Calif., June 27, 1939.

appreciable amounts of dyes and hydrocarbons and other substances that are otherwise notoriously insoluble in water. The product is a true stable colloidal solution maintaining reversible equilibria with its constituents and subject to the ordinary methods of physical chemical study.

Here again we find the same problem being approached in a very different manner by scientific workers in other fields. The organic and biochemists have labeled this "the choleic acid principle" because bile acids share this property of detergents. Desoxycholic acid carried the fat-soluble and otherwise water-insoluble vitamins as has been shown by several investigators at Berkeley. This explains how such materials are carried in the blood stream and can take part in physiological processes. It gives a possible clue to the mechanism of digestion in animals or of the behavior of chlorophyll in plants. It has been used by the Mayo Clinic to render available Vitamin K which prevents certain persons from bleeding to death after operations.

It is evident that there is a clear and simple rationale behind the behavior of these almost innumerable and easily varied colloidal electrolytes. They are subject to such laws as the phase rule of Willard Gibbs. In fact, the phase relations of ordinary soap solutions are as definite as those of brass or steel, but far more complicated and much more interesting.

From the way in which I have developed the opening theme of this subject, it is clear that great stress is being placed upon a knowledge of actual structure. For this the most important tool is the examination by X-rays. Remarkable advances have been made in the X-ray study of proteins, wool, hair, feathers, silk, muscle, rubber, synthetic rubbers, the natural gums, and other polysaccharides. The study of these natural polymers, which include also all the textiles, has inspired all large chemical organizations throughout the world to discover and design new polymers of desirable characteristics due equally to the interior structure of the particle and the exterior groups which together govern its mechanical and chemical properties, some of which are unexpectedly favorable. These newly created substances are commonly referred to as the resins and plastics, and they promise another minor industrial revolution. They are making all nations more self-sufficient, because they can replace expensive imported materials by new ones of superior properties. Thus a metal-like tin can be advantageously supplanted by a plastic, *e. g.*, in steel rolling, with only water a sa lubricant. Some of the new properties are rather unexpected, such as the base exchange with the exposed groups of certain resins which make them available as water softeners. We need no elaboration of the remarkable possibilities opened up by these plastics when we see what a prominent and attractive place they hold at both the Golden Gate and New York Expositions, and when we read in the latest issue of our *Scientific American* that a complete airplane fuselage can be molded in two hours, in one-half of the time required ordinarily to finish one square foot of an ordinary plane.

An equally important colloid tool is the centrifuge, more specially in the form where it is freed from convection or stirring and called the ultracentrifuge. The original development of this invaluable means for determining particle size is due to the genius of Svedberg, but more recently equally powerful and incomparably less expensive forms have been developed by Beams, Wyckoff, and at Stanford University. Now we have models which should be available in every university and industrial laboratory, both for research and for instruction. The least expensive and potentially the most powerful and versatile are the opaque or analytical ultracentrifuges, where the liquids are taken out and analyzed by any appropriate method. They are no longer confined to the study of large colloidal particles, but are successfully applied in sedimenting ordinary molecules.

Another important function of centrifuges and ultracentrifuges is to concentrate and segregate interesting materials or important impurities that might otherwise be present only in inaccessible traces. In colloidal matter their presence or their complete elimination may make an all-important difference in behavior.

A third tool which is producing unexpectedly definite results with protein systems is the observation of movement in the electric field particularly in electrophoretic equipment developed by Tiselius and MacInnes, where the effects are kept under prolonged observation and intensified by the expedient of mechanically compensating their electrical movement, while keeping them under critical optical observation with the well-known Schlieren method of Toepfler. This separates even very similar constituents. In fact, it has been found that protein constituents that stay together in moderate electrical fields will in higher fields travel separately at different rates. Dr. Eloise Jameson has also found that it is possible by mere feeding to alter the proteins of the blood, and even to introduce antibodies which can be separated in the electrophoretic cell and afterward studied by the methods of bacteriology, or in the ultracentrifuge, or in the biochemical laboratory.

The proteins occupy the forefront of attention and are the subject of a symposium somewhere every few months.

The methods of chemistry, and study with enzymes, and surface phenomena, all show that proteins have a long chain poly-peptide structure. X-rays confirm this for many proteins such as silk, wool, and keratins, but X-rays and the ultracentrifuge have shown that some proteins like egg albumin, hemoglobin, and insulin have a nearly spherical or globular form, until they are denatured or spread on surfaces. The cyclol cage structure suggested to account for this has not found favor, and some alternative, explaining proteins as built up from sub-units, is being sought.

Another colloidal material recently come into prominence whose structure has been determined by X-rays, and whose fine particles can be segregated by a high-power centrifuge and whose exposed reactive groups can be altered and replaced in an electric field is clay. The

replacement of these active groups by others is familiar in the formation of deltas at the mouths of rivers where the silt reacts with the heavy metal salts in sea water. Clay consists of sheets laminated like a club sandwich whose surfaces are all different from their exposed edges. All this is of primary interest in soil science, but the triple laminated or bentonite type is especially useful in the drilling muds of the petroleum industry. The mechanical properties of these muds can be changed in a spectacular way by the addition of very small amounts of tanning agents. This is no strained analogy but turns out to be a direct parallelism with the tanning of swollen skin to make leather by putting inactive groups upon the torn exposed ends and edges and by blocking off any other reactive groups on the surface.

It has long been known that a suspension of the finest clay particles when evaporated yields a highly tenacious film, but Hauser has produced commercially promising films—wrapping and insulating materials of this nature that are water- and fire-resistant. This even promises to be the beginning of an inorganic plastics industry, a distinct extension of the age-old ceramics.

Much theoretical speculation has appeared in recent years to account for the curious phenomena of tactoids, Schiller layer thixotropy, and coacervation, to give each its technical title.

Tactoids are the doubly refracting concentrated patches that spontaneously appear in dilute colloidal solutions of certain rod-shaped or flat particles, such as vanadium pentoxide or the tobacco mosaic virus protein. Thixotropy has long been familiar as that property of many colloid systems of setting to a jelly when undisturbed, and liquefying each time that they are shaken or stirred. Evidently some structure is temporarily destroyed, which subsequently rebuilds itself. Coacervation is the mutual precipitation out of solution of two colloids added together, familiar for example in one of the chief methods of disposal of sewage. Some of these coacervates may be readily separated again into their two constituents by suitable treatment, as for example, in an electrical field.

In all these phenomena there are three current alternative explanations; one involving loose interlocking of the particles at certain points of contact; another, less favored, that the particles are surrounded by liquid that is rendered practically rigid by the proximity of the particles; and the third, now much discussed, that the particles may be held apart at almost microscopic distances by a balance of attractive and repulsive forces. The Dutch and Freundlich consider that the electrical forces are repulsive over great distances. They balance this repulsion by deducing a residual van der Waals' attractive force increasing with the size of the particle, and thus explain how the particles are held in more or less stable array at a distance from each other. On the other hand Langmuir and Levine revert to the classical view that since the system as a whole is electrically neutral and the charged particles are interspersed with equal amounts of oppositely charged ions, the electrical forces are not repulsive, but attractive. Langmuir then calculates an extra osmotic effect to produce a repulsion to balance this electrical attraction. The author, however, is impressed by the fact that thixothropy is most prominent in non-conducting, non-aqueous liquids where there are no ions either to attract or repel. Coacervation, too, occurs in these completely non-ionizing liquids. Excellent although most annoying examples are found by industrialists who attempt to put asphaltic bitumen and coal tar pitch into the same oil, although the whole system consists almost entirely of hydrocarbons.

In general, the reviewer is impressed by the fact that most of the prominent phenomena of colloid systems have been demonstrated in non-aqueous, non-ionizing media, and therefore he questions these electrical effects as being responsible for the same phenomena in aqueous systems.

In the foregoing review it will be noticed that the only subjects mentioned are those that are being studied simultaneously in many countries, chiefly in Russia, Holland, England, Japan, the United States, and elsewhere.

The PRESENT STATUS *of* CHEMISTRY *in* NEGRO COLLEGES

HAROLD W. WOODSON[1]

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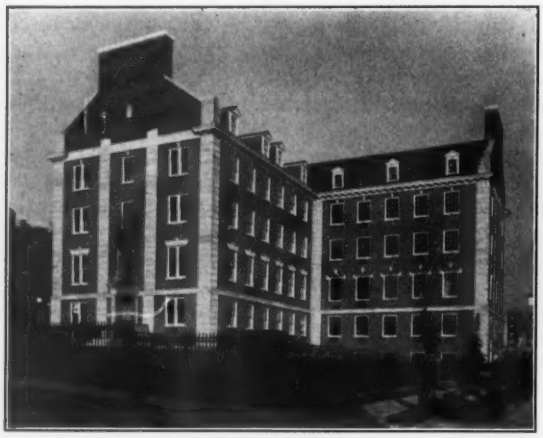
IN MANY aspects the growth and development of chemistry in Negro colleges has been phenomenal, considering the relative short period of time for such a development. In 1916 there were twelve Negro institutions of higher learning[2] which increased to one hun-

[1] Present address: 6113 Calumet Avenue, Chicago, Illinois.

[2] ANON., "Negro training facilities for higher grade jobs," *Mo. Labor Rev.*, **49**, 629 (1939).

dred twenty-one institutions in 1936. Sixty were accredited by State Education Departments, regional accrediting bodies, or both. Sixty-nine colleges were four-year institutions, seventeen were teacher training institutions, and thirty-five were junior colleges. Reference to the literature[3] shows that educationally the Negro



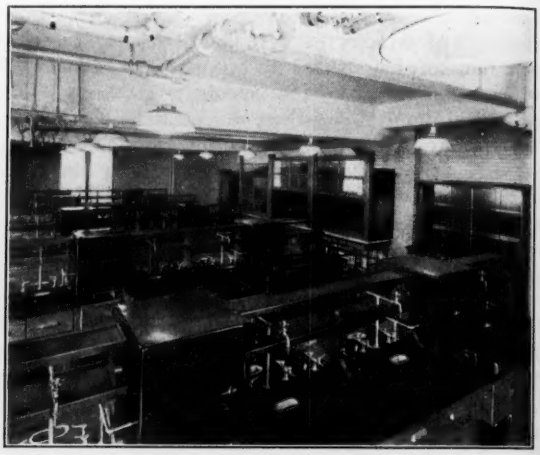
CHEMISTRY BUILDING, HOWARD UNIVERSITY, WASHINGTON, D. C.

has made enormous strides in chemistry. The first Ph.D. in chemistry conferred on a Negro was in 1916. Dr. St. Elmo Brady, Head of the Department of Chemistry, Fisk University, Nashville, Tennessee, was the

ELEMENTARY PHYSICAL CHEMISTRY LABORATORY, HOWARD UNIVERSITY, WASHINGTON, D. C.

recipient. Since that time fourteen Negroes have received the doctorate in chemistry.

Notwithstanding these facts there are many difficulties that confront the Negro contemplating a career in science. DuBois'[4] study of outstanding Negro scientists



A GENERAL CHEMISTRY LABORATORY, HOWARD UNIVERSITY, WASHINGTON, D. C.

gives a picture of men who have had the mental equipment requisite for scientific accomplishment and who have done work of a high order, but who never had the best facilities or even a good opportunity to accomplish

AN ELEMENTARY ORGANIC LABORATORY, HOWARD UNIVERSITY, WASHINGTON, D. C.

first-rate work opened to them. Another serious handicap to the Negro chemist is the limited opportunity for professional employment in chemical and allied industries.

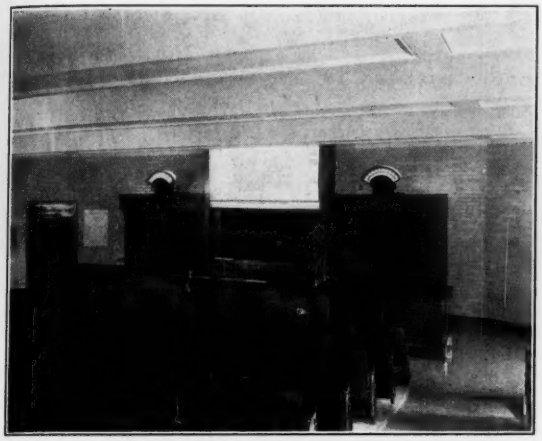
In a previous paper[5] the author discussed under-

[3] CALLOWAY, "Opportunities for the Negro in chemistry," *Opportunity*, **15**, 295–8 (1937).
GEISER, "The Negro in American chemistry," *ibid.*, **13**, 43–5 (1935).
GREEN, "Sixty years of doctorates conferred upon Negroes," *J. Negro Educ.*, **6**, 30–7 (1937).

[4] DUBOIS, "The Negro scientist," *Am. Scholar*, **3**, 309–20 (1939).

[5] WOODSON, "A survey of chemistry curricula in Negro colleges," *J. Negro Educ.*, **8**, 644–8 (1939).

graduate curricula. The present paper describes the present status of undergraduate and graduate chemistry; training, number, and distribution of faculty members; faculty publications; and laboratory facilities. Data for this study were obtained by correspondence with department heads of chemistry, and by analysis of the catalogs and bulletins of thirty-eight Negro colleges. Colleges were selected from the following fifteen states and the District of Columbia: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana,



LECTURE HALL, HOWARD UNIVERSITY, WASHINGTON, D. C.

Maryland, Mississippi, Missouri, North Carolina, South Carolina, Tennessee, Texas, Virginia, and West Virginia. Of thirty-seven of these institutions, nineteen have an enrolment of seven hundred or more, eight have an enrolment from four hundred to six hundred ninety-nine, and ten have an enrolment of less than four hundred students.

UNDERGRADUATE CHEMISTRY[6]

From a total of thirty-eight colleges:

30 colleges offer 2 semesters of general chemistry.
26 colleges offer 1 semester of qualitative analysis.
24 colleges offer 1 semester of quantitative analysis.
32 colleges offer 2 semesters of organic.
15 colleges offer 2 semesters of physical.
9 colleges offer 1 semester of food.
8 colleges offer 1 semester of biochemistry.

Five different types of general chemistry are noted, although the assignment of students to different sections or courses on the basis of previous knowledge is practiced by less than five per cent. of the colleges studied. Other courses offered are advanced qualitative and quantitative analysis, organic analysis, agricultural chemistry, teaching of chemistry, and history of chemistry.

Harrow's[7] study of undergraduate "colleges with $2,000,000 endowment or over" included only two Negro institutions, Tuskegee Institute which offered biochemistry and food chemistry, and Hampton Institute which offered food chemistry.

GRADUATE CHEMISTRY

There are three Negro universities that offer the Master's degree in chemistry. They are: Atlanta

Photograph by J. E. Hemphill

SCIENCE HALL, JOHNSON C. SMITH UNIVERSITY, CHARLOTTE, NORTH CAROLINA

University, Atlanta, Georgia, Fisk University, Nashville, Tennessee, and Howard University, Washington, D. C. Graduate work[8] has been offered at Atlanta Uni-

SILSBY SCIENCE HALL, TALLADEGA COLLEGE, TALLADEGA, ALABAMA

versity since 1929, at Howard University since 1927, and even earlier at Fisk University.

These universities are well equipped to train graduate students properly. Howard University's new chemistry building[9] was formally opened on October 26,

[6] WOODSON, *J. Negro Educ.*, **8**, 644–8 (1939).
[7] HARROW, "Biochemistry offered in colleges other than universities and medical schools," J. CHEM. EDUC., **14**, 527 (1937).
[8] FRAZIER, "Graduate education in Negro colleges and universities," *J. Negro Educ.*, **2**, 329–41 (1933).
[9] "The new chemical laboratory of Howard University," *Ind. Eng. Chem., News Ed.*, **15**, 36 (1937).

1936. It is five stories high and, including the attic, accounts for approximately 1,000,000 cubic feet in capacity and a total floor space of more than 34,000 square feet. All the laboratories are provided with pre-

TABLE 1

Colleges Studied

ALABAMA
The State Teachers College
Talladega College

ARKANSAS
Agricultural, Mechanical, and Normal College
Philander Smith College

DISTRICT OF COLUMBIA
Howard University
Miner Teachers College

FLORIDA
Florida Agricultural and Mechanical College

GEORGIA
Clark University
Morehouse College
Morris Brown College
Paine College
Spelman College

KENTUCKY
Louisville Municipal College

LOUISIANA
Dillard University
Xavier University

MARYLAND
Morgan College

MISSISSIPPI
Alcorn Agricultural and Mechanical College
Tougaloo College

MISSOURI
Lincoln University

NORTH CAROLINA
Agricultural and Technical College
Livingstone College
Johnson C. Smith University

OHIO
Wilberforce University

OKLAHOMA
Colored Agricultural and Normal University

PENNSYLVANIA
Lincoln University

SOUTH CAROLINA
Benedict College
Claflin College
State Agricultural and Mechanical College

TENNESSEE
Fisk University
Knoxville College
LeMoyne College
Tennessee State

TEXAS
Bishop College
Samuel Huston College
Wiley College

VIRGINIA
Hampton Institute
Virginia State

WEST VIRGINIA
West Virginia State

heated air ventilation, gas, water, air, and three-phase alternating current of 110 volts. The advanced general laboratories, research rooms, and private laboratories include, in addition to the above services, hot water, steam, direct current of 110 and 220 volts, battery currents from 2 to 120 volts in steps of 2, and variable high-frequency current of 500 to 10,000 cycles. Atlanta University[10] has the facilities of the laboratories of Morehouse College and Spelman College, since on April 1, 1929 an arrangement was completed among Atlanta

TABLE 2

INSTITUTIONS IN WHICH GRADUATE DEGREES WERE EARNED

Institution	*Ph.D.*	*Master*
Atlanta		2
Catholic University of America	1	
Chicago	1	4
Columbia		9
Cornell	1	4
Fisk		1
Harvard	2	
Howard		2
Illinois	1	4
Indiana		2
Indiana State		1
Iowa State	1	
Johns Hopkins	1	
Louisiana State		1
McGill	1	
Michigan	1	1
Minnesota		1
New York		1
Oberlin		1
Ohio		1
Pennsylvania		1
Southern California		1
Wittenberg		1
Colleges not named	3	5
Total	13	43

University, Morehouse College, and Spelman College for the affiliation of the three institutions in a university plan, the graduate work to be conducted by Atlanta University, the college work to be done by Morehouse College and Spelman College. Fisk University opened its new chemistry building in the fall of 1931.

TABLE 3

DISTRIBUTION OF CHEMISTRY INSTRUCTORS

Number of institutions	*Instructors per institution*	*Total instructors*
17	1	17
13	2	26
4	3	12
1	4	4
1	7	7
Total 36	1.83	66

There were two students registered for graduate work in chemistry at Atlanta University[11] for 1938–1939. The average yearly registration of graduate students in chemistry at Howard University for the last few years is about twelve, but the department graduates only two or three students yearly.[12]

[10] Atlanta University Bulletin, Series III, April, 1939, No. 26, p. 17.

[11] *Ibid.*, pp. 60–1.

[12] Communication from Dr. J. L. Shereshefsky, Head of Department of Chemistry, Howard University, Dec. 17, 1939.

Although the number of graduates from these three institutions is small, they are of unusually high calibre. One of the recent graduates from Howard University is now on the research staff of McGill University, where he is holding the position of special lecturer. Two other Howard graduates are holding Rosenwald Fellowships while pursuing work toward the doctorate at outstanding educational institutions, and several are holding teaching positions in high schools and colleges. Out of a total of sixty-six Negro college chemistry faculty members, two hold Master's degrees from Atlanta University, one from Fisk University, and two from Howard University.

THE FACULTIES

The success of graduate training not only depends on adequate laboratory and research facilities, but to a greater extent on the faculty members. The chemistry department of Atlanta University consists of two members, one of whom holds the Ph.D. degree from the University of Chicago, and one who holds the Master's degree from Columbia University with considerable graduate work above this degree. Fisk University has three members, two of whom hold the Ph.D. degree, one from the University of Illinois and one from Iowa State College. The other member holds the Master's degree from the University of Chicago. The chemistry department of Howard University consists of seven members, five of whom are holding the Ph.D. degree from prominent institutions in this country, and two are holding the Master's degree. Of the latter one is now on leave, studying for his doctorate at the California Institute of Technology.

From a total of thirty-six Negro colleges there were thirteen instructors (about twenty per cent.) holding the Ph.D. degree, forty-three (about sixty-five per cent.) holding the Master's degree, and ten (about fifteen per cent.) with the Bachelor's degree. Many of the instructors have done considerable graduate work in advance of the highest degree reported. Table 2 shows the institutions at which graduate degrees were earned by these instructors. A substantial majority of the doctorates were earned at America's outstanding universities. Table 3 shows the distribution of chemistry instructors in thirty-six Negro colleges. Forty-seven per cent. of the colleges in this study had one instructor of chemistry.

PUBLICATIONS

The teacher's success is to be determined by the efficiency of his teaching as well as his research work. The instructor in the Negro college is contributing results of his research in the recognized journals. The following bibliography is not complete, but will give a representative survey of material recently published by the instructors.

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ACID-BASE REACTIONS *in* NON-PROTONIC SOLVENTS

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THE growth of our ideas of acid-base phenomena has been mainly one of expansion to include increasing numbers of solvent systems. At first these were limited to the water system by definition. Then, by the expedient of defining bases without recourse to hydroxyl ions, Brønsted broadened our concept to include any solvent having an exchangeable proton. This broadening served very well to account for reactions in liquid ammonia and other protonic solvents. It no longer seems sufficient to limit ourselves to protonic solvents by the retention of the hydrogen ion or proton as an essential property of an acid.

The properties and reactions which may be taken as indicative of acid-base relations in a solvent are generally accepted to be

(1) electrolytic solutions;
(2) well-defined acids, bases, and salts;
(3) neutralization reactions giving rise to salts and showing definite potentiometric endpoints; and
(4) formation of solvates.

In the tabulated list above (3) is the essential test for acid-base reactions; (4) is not, in itself, positive evidence but seems to be present in all systems showing such relationships.

In support of the statement that our concept must be extended beyond the restrictions placed upon it by the definition of acids in terms of protons, a short review of non-protonic solvents seems fitting. The most thoroughly studied of these is liquid sulfur dioxide. Jander and co-workers (*1*) have pointed out reactions in this solvent which answer all the tests presented above. The solvent is in itself slightly ionized. Its autoionization is postulated to give rise to solvated thionyl ions and sulfite ions.

$$3SO_2 \leftrightarrows (SO.SO_2)^{+2} + SO_3^{-2}$$

By analogy thionyl chloride should be an acid, and caesium sulfite should be a base. On adding a sulfur dioxide solution of thionyl chloride to a sulfur dioxide solution of caesium sulfite it was found that a typical neutralization reaction appeared, the products of which were caesium chloride and solvent.

$$SOCl_2 + Cs_2SO_3 \leftrightarrows 2CsCl_2 + 2SO_2$$

This reaction could be followed potentiometrically to give a typical neutralization curve. The study of acids was extended to thionyl acetate, thionyl bromide, and thionyl thiocyanate, which were prepared from thionyl chloride by metathesis reactions.

Solvation followed by solvolysis, and a change in the relative ratio of solvent ions, was encountered when ammonia or organic amines were used. On addition of ammonia to liquid sulfur dioxide two molecules of ammonia reacted with two molecules of sulfur dioxide.

$$2NH_3 + 2SO_2 \leftrightarrows \left(\begin{matrix}NH_2\\NH_2\end{matrix}\!\!>\!SO\right)^{+2} SO_3^{-2}$$

This is strictly analogous to the reaction between ammonia and water to give ammonium hydroxide.

$$NH_3 + H_2O \leftrightarrows (NH_4)^+OH^-$$

The sulfite resulting from addition of ammonia to liquid sulfur dioxide may be neutralized by a solution of thionyl chloride.

Although it seems that the presence or absence of amphoterism in a system is not an essential adjunct of acid-base reactions, it is often encountered. Jander has pointed out an example of such a reaction in liquid sulfur dioxide. An aluminum chloride solution in liquid sulfur dioxide, when treated with a tetramethylammonium sulfite solution in liquid sulfur dioxide, gives a precipitate of aluminum sulfite.

$$2AlCl_3 + 3[(CH_3)_4N]_2SO_3 \leftrightarrows Al_2(SO_3)_3 + 6(CH_3)_4NCl$$

The precipitated aluminum sulfite was soluble in an excess of tetramethylammonium sulfite solution.

$$Al_2(SO_3)_3 + 3[(CH_3)_4N]_2SO_3 \leftrightarrows 2[(CH_3)_4N]_3Al(SO_3)_3$$

From the solution thus formed aluminum sulfite could be reprecipitated by a solution of thionyl chloride.

$$3SOCl_2 + 2[(CH_3)_4N]_3\,Al(SO_3)_3 \leftrightarrows Al_2(SO_3)_3 + 6(CH_3)_4NCl + 6SO_2$$

For further details concerning liquid sulfur dioxide as a solvent, the reader is referred to the original work of Jander.

Similar systems have been pointed out by Germann (*2*) and by Smith (*3*). The first of these is liquid phosgene which on electrolysis gave carbon monoxide and chlorine.

$$COCl_2 \xrightarrow{\epsilon\ \text{cathode}\quad\text{anode}} CO + Cl_2$$

In this solvent carbonyl compounds appeared as acids and metal chlorides as bases. The second is selenium oxychloride in which the characteristic ions are the selenyl ion (SeO_2^{+2}) and the chloride ion (Cl^-).

Some evidence for acid-base relationships in non-protonic solvents may be obtained from work which was carried out for other reasons. Much of this evidence was found by workers who were not interested directly in this field, so they did not pursue their studies to a final conclusion in respect to acid-base effects. North and co-workers (*4*) in studying sulfuryl chloride and thionyl chloride noted reactions which suggest that such effects should be encountered in these solvents. The work of Schenck and Platz (*5*) upon the production of sulfur monoxide from thionyl chloride also points toward the occurrence of acid-base reactions.

It seems quite probable, also, that acid-base phenomena may be present in certain organic solvents which are normally considered to be non-ionic and it may be suspected that the character of the solvent is less important than the character of the solute. Two examples are cited, which, although they do not prove the presence of acid-base reactions, at least indicate that such reactions might be found if sought. Folin and Flanders (*6*) found that a solution of common acids in benzene or other non-polar solvents could be titrated by solutions of sodium ethoxide in ethyl alcohol. Platnikov (*7*) has developed a method for electroplating aluminum from a solution of aluminum bromide in ethyl bromide. Many more such examples may well arise in the mind of the reader.

The second portion of this discussion of acid-base relationships in non-protonic solvents will be devoted to the theories and concept which have to date been advanced to generalize the definitions of acids. It seems fitting to analyze each upon its own merits and permit the reader to make his choice.

The first to be taken up is that proposed by Germann (*8*) some years ago. This treatment lays emphasis upon solvation in the solution and ionization processes. It requires that the solvent be autoionizing and defines the acids and bases of any solvent system in terms of the ions characteristic of the solvent. A "solvo" or "true" acid is defined as a solute which on solution gives rise to the cation characteristic of the solvent and to an anion which contains the anion of the solvent. Thus by this definition hydrogen chloride dissolved in water would not be a "solvo" or "true" acid since it results in a simple anion which does not contain the anion of the solvent. A "solvo" base is a solute which upon solution gives rise to the anion of the solvent and simple metal cations.

The chief objection to this scheme is, of course, that it does not allow such solutions as hydrogen chloride in water or thionyl chloride in sulfur dioxide to be treated as acid solutions. It would, however, lead to an explanation of the acidity of metal ions in a solution similar to that used by Brønsted for protonic solvents. It may be said of this concept of acids and bases that it has removed the arbitrary limitation of acids to protonic solvents, but has replaced it by the equally arbitrary restriction based upon the solvation of the anion of the acid.

The simplest scheme for the generalized treatment of acids and bases is that of Cady and Elsey (*9*). An acid is defined as a solute which gives rise to a cation characteristic of the solvent, a base as a solute which gives rise to an anion characteristic of the solvent. The restriction made is that the solvent must be only slightly ionized, in order that there will be a driving force for neutralization reactions.

Such an approach is perhaps the most generally useful because of its simplicity, but it contains no fundamental implications or limitations which might lead to further research. This seems a valid objection to any such theoretical treatment.

Several years ago Lewis (*10*) proposed that acids and bases be referred to without regard to the solvent. A basic substance was defined as one in which there was an atom with a free pair of electrons available to complete the configuration of another atom. An acid was defined as a substance containing an atom which may accept such a free pair of electrons from another atom. This approach has recently been somewhat modified by Smith (*3*). He defines an acid as a solute whose molecule (neutral or charged) accepts a pair of electrons from the molecule or anion of the solvent. Conversely,

a base acts as the donor of a pair of electrons to an ion or a molecule of the solvent.

This modification leads to essentially the same results in protonic solvents as does the Brønsted concept, but has the added advantage that it may be applied to non-protonic solvents. Thus ammonia is a base in either water or liquid sulfur dioxide, since the ammonia molecule acts as the donor of a pair of electrons to the cation of either solvent. The treatment given seems quite adequate in that it places the phenomena upon a fundamental basis.

Recently, Wickert (*11*) has proposed a more complex explanation of the subject based upon electronic structures. His first specification is that a "water-like" solvent is necessary. The term "water-like" solvent is applied to substances which ionize to give a cation having an incomplete electron configuration and an anion having a complete electron configuration.

$$H_2O \rightleftarrows H^+ + :\ddot{O}: \; H^-$$

$$2SO_2 \rightleftarrows \ddot{S}:\ddot{O}:^{+2} + :\ddot{O}:\ddot{S}:\ddot{O}:^{-2} \quad (:\ddot{O}: \text{ above S})$$

This definition restricts the term to slightly ionized solvents since it seems from energy considerations that such an ionization could not proceed to any marked degree without the addition of some other component. The definition also precludes from consideration such solvents as molten sodium chloride and molten sodium hydroxide, since these on ionization give cations having a complete electron configuration.

$$NaCl \rightleftarrows :\ddot{N}a:^{+} + :\ddot{C}l:^{-}$$

$$NaOH \rightleftarrows :\ddot{N}a:^{+} + :\ddot{O}:H^{-}$$

In such a solvent an acid is a substance which on solution gives rise to cations having an incomplete electron configuration and to anions having a complete electron configuration.

From the combination of the above definitions it is possible to draw certain conclusions.

(1) Any acid which gives rise to the same ions in the pure state that it does in solution, must itself be a "water-like" solvent in the pure state.

(2) Any substance which is an acid in one "water-like" solvent is an acid in any other "water-like" solvent in which it undergoes a similar ionization.

A series of ionization equations may help to clarify these statements. Antimony trichloride and antimony tribromide may be seen to be "water-like" solvents. The tribromide is an acid in either the trichloride or in water.

"Water-like" Solvent $\quad SbBr_3 \rightleftarrows \ddot{S}b^{+3} + 3:\ddot{B}r:^{-}$

"Water-like" Solvent $\quad SbCl_3 \rightleftarrows \ddot{S}b^{+3} + 3:\ddot{C}l:^{-}$

Acid $\quad SbBr_3 \overset{H_2O}{\rightleftarrows} \ddot{S}b^{+3} + 3:\ddot{B}r:^{-}$

Acid $\quad SbBr_3 \overset{SbCl_3}{\rightleftarrows} \ddot{S}b^{+3} + 3:\ddot{B}r:^{-}$

Bases and salts are defined as substances which give rise to cations and anions, both of which have complete electron configurations. Bases are distinguished in a particular solvent by the fact that they give the same anion as the solvent. From this it may be seen that a substance which is a base or a salt can never become an acid or a "water-like" solvent unless its manner of ionization varies with conditions.

The final analysis of this treatment leads to the conclusion that there are only two types of ionic compounds: those which ionize as acids or "water-like" solvents, and those which ionize as salts or bases. All acid-base phenomena become reactions between members of the two classes to give rise to new members of the two classes. From this it appears that there is no essential distinction between the processes of neutralization, displacement, and solvolysis. The only differences encountered are represented by the variation in the factors which cause the several reactions to continue to a measurable extent. The three reactions listed below are of like nature.

(1) $\quad NaOH + HCl \rightleftarrows NaCl + H_2O$

(2) $\quad BaCl_2 + H_2SO_4 \leftrightarrows BaSO_4 + 2HCl$

(3) $\quad NaC_2H_3O_2 + H_2O \leftrightarrows HC_2H_3O_2 + NaOH$

Such definitions upon the basis of the electron configurations of the ions seem fairly satisfactory. However, certain questions do arise. It seems hardly likely that anhydrous liquid aluminum bromide should vary greatly in properties from anhydrous liquid antimony tribromide. Both compounds are typically covalent, exhibiting poor conductivity and low melting points, the first melting at 97.5°C., the second at 96.6°C. Upon the basis of Wickert's definition antimony tribromide is a "water-like" solvent as shown by its ionization to trivalent antimony ions and bromide ions. By the same definitions aluminum bromide would be a fused salt as it gives aluminum ions, having a complete electron configuration, and bromide ions.

$$SbBr_3 \rightleftarrows \ddot{S}b^{+3} + 3:\ddot{B}r:^{-}$$

$$AlBr_3 \rightleftarrows :\ddot{A}l:^{+3} + 3:\ddot{B}r:^{-}$$

It seems necessary only to reassert that no completely satisfactory explanation of acid-base phenomena has as yet been developed. This is true for the reason that the limitations of the concepts have not, as yet, been experimentally determined. No arbitrary limitations can be expected to be satisfactory substitutes for the experimentally determined limitations. For this reason chemists must expect periodic revamping of the prevailing ideas concerning the nature of acids and bases.

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ABRIDGED REPORT *of the* COMMITTEE *on* CHEMICAL EDUCATION *of the* NON-COLLEGIATE TYPE

OBJECTIVE NO. 2, PART 2

R. E. BOWMAN, *Chairman*

Wilmington, Delaware

PART One of this report was presented (*1*) soon after the present administration took over at Washington. There have been good reasons for delaying discussion in a period of rapid and serious economic and social change. The types of school have not altered in the meantime but have been regaining momentum after some curtailment. The chemical companies held most of their technicians through the ebb tide or called them back to work as they regained ground. The National Recovery Act brought chemical codes for a time. Later legislation now brings a fixed minimum wage and maximum hours. The costs of chemical education have continued to rise, making it more difficult for the technician to give up employment and return to school. For a time one excellent young foreman contributed seventy per cent. of his wages to the support of brothers and sisters out of work. But it kept him from returning to the University and entirely altered his life.

The work of the Committee has both an educational and a social aspect which leads us to feel that its work should continue. One of us feels that its work is complete. Others feel that a greal deal is yet to be done. Our comments passed twice about the circle of members.

Considerable changes have occurred in the industrial point of view (*2*). A pamphlet (*3*) from the Universal Oil Products Company was circulated and is referred to in the discussion, which dealt with the qualifications for operators and foremen or inspectors. To condense the opinions of six persons within the allotted space and still do justice is not an easy task. The death of Dr. Allen Rogers, former Chairman of this Committee, to whom we all are greatly indebted, leads me to quote his opinions more fully than the rest. It is his last word to the Chemical Revolution, as Dr. Hale calls it. Trusting that the abridgement will be acceptable, one plunges at once into the task.

Dr. Allen Rogers: There are two separate problems involved—those of the laboratory technician and the plant operator. The *lab technician* in many cases is a boy just out of high school who by chance has obtained a job in the laboratory and finds the work interesting. He may find ways and means to get a degree from college or technical school or turn to an intensive chemistry course. If he is unable to do this, the night school, correspondence, and extension schools are tried. The unambitious boys will plod along and be satisfied with routine chemical work the rest of their lives. Every encouragement should be given to the ambitious boy, plus recognition of his accomplishment. He should never be made to feel that he is a ditch digger who can never get out of the hole.

The *plant operator* of the old rule-of-thumb type must be replaced by a man with technical training. He is not hampered, however, by the lack of a college degree. He should understand the fundamentals of the science of chemistry, he should have a working knowledge of mathematics and the physical elements of engineering, plus horse sense. Many institutions will provide him with sound training. The technically trained man of

this type is able to work in harmony with the chemist, research man, and engineer, because they speak the same language and are not hampered by the thought of degrees. The field is wide and offers many promising opportunities for the man with technical training of the non-college type. The Committee is just starting its work. Its suggestions should be considered by manufacturers. It should appeal to them to encourage young men to advance themselves. An idea of each class of training should be included in the appeal.

Dr. Morris Lawrence: The reply of Firm Number 14 (in Part One) interested me—two of this firm's best chemists had been high-school graduates who had taken correspondence courses. I wish Question One had asked more definitely as to whether the employing firms approved of correspondence school graduates. I believe it would have given some interesting results. We enrol approximately twelve hundred per year in our various chemistry courses (a list of nineteen courses follows). We also offer special courses to students who do not wish the complete courses. A third questionnaire would not justify the probable expense involved or the results obtained.

Dr. A. P. Tanberg: The trend is toward the technical high school boy over eighteen years who seems best for our purpose. The will to complete a high-school course plus other characteristics is a measure of the fitness of boys to do this sort of work. Personal fitness such as indicated in Mr. Matson's summary (*3*) plus resourcefulness in the boy who has completed a high-school course is important, as the high school selects or sorts them before the boy applies for the job. The requirements of lab technicians and plant operators are not necessarily the same. Many high-school boys graduate through persistence rather than to fit themselves for a specific job. There is a confusion between fitness for a job and fitness for promotion. Courses in public speaking, rhetoric, or psychology might help a man advance from operator to foreman or supervisor. Statistical data may be influenced by business conditions which put superior men in jobs lower than their ability levels. A married man of low educational qualifications may be retained while a young single man of higher qualifications may be laid off. Ambitious helpers frequently leave to go to college. We would be better off if we employed a less ambitious boy of less natural ability. Research helpers cannot advance very far and we seldom employ a high-grade four-year chemist.

Types of evening training open to technicians and operators are seldom as good as regular college courses. Two boys worked with us from 4 to 12 P.M. to secure funds for all-day work at the University of Delaware. Boys can be classified into those satisfied with their future and those willing to do any remunerative work to enable them to get first-class college training. My experience has been with research rather than with production. Our boys run errands, clean apparatus, make a few routine tests, and so forth. We never intentionally depend upon them for important observations in connection with the course of an experiment.

Dr. R. E. Rose: The worth-while boy should be encouraged to get better fundamental knowledge of his occupation by further training and study, after he is sure (through employment) that he really likes the work and wants to understand it better. Courses should not be taken for effect when there is no real willingness or capacity for additional basic information. The belief that every youngster should have facilities for deeper scientific training is unsound. An increasing per cent. of our population is condemned to routine jobs calling for no basic information beyond grade school. Technical training is no more necessary than for an elevator operator to be trained in the knowledge of electrical theory and mechanism. We must reconcile the average and below average boy to stay on a job by emphasizing the essential dignity of such work and its importance to our civilization. Existing educational facilities are quite adequate. Much high-school work should be turned into plain trade school preparation for overall jobs. An ambitious young man can always get the technical training he wants if he has a little help in learning to take advantage of his opportunities. I favor advisory groups of teachers plus representative men. At present only chance determines a youngster's choice of employment. Ninety-nine men and women out of a hundred do work calling for no more than grade-school preparation. We only harm by encouraging those of this group to think they are fitted for something better. Mental capacities are almost as fixed as life expectancies. The Franklin Union Report (*4*) seems typical of an unsound attitude of mind. It overlooks essentials and magnifies minor points. Our Committee has done all that can be expected of it although more remains to be done. It would not be wise to send questionnaires to those who have secured non-college technical education.

Dr. H. A. Ernst: One technician is employed approximately for every two college men. No existing program trains them for junior positions. They drift into the chemical field. The industry bears the expense of weeding out the unfit and disinterested, but the school could do so at less financial and social expense. Chemistry is a strongly organized science, but no attempt has been made to determine pre-employment qualifications. The selection of boys is subjective, extremely unscientific, and therefore expensive.

High-school training is selective. The weak drop by the wayside. Boys unable to enter high school for economic reasons may have more real aptitude for the chemical industry than those who do. No real conclusions can be drawn from Question C without checking the replies against state requirements. The age of eighteen is in line with the average age of the high-school graduate. One in two now attends high school on account of the economic and social situation. Many of these should be working who are now being "exposed" to formal training procedures developed for other purposes. Should the high-school course be changed to

meet the requirements of industry for high-school graduates? There is no proof that the mental training of the high school can be transferred to other fields of training.

A survey of workers of less than college grade would lead to valueless, biased results, since they represent a selected group and their replies would be based upon too narrow a premise. Training in chemistry for boys unable to attend college or technical school should be provided. The chemical industry contributes its large share to the $23,768,000 per annum Smith-Hughes and George-Deen Law appropriations and the states match this money dollar for dollar, at least. The chemical industry should secure better trained juniors in return for its taxes. The live wires among them will continue their training and work for associate engineering degrees. The field has not been scratched. There is still work for the Committee to do. Conclusions and recommendations should be set forth.

R. E. Bowman: Social and economic forces combine to raise the age at which an entry into industry is made. The normal boy has had time to complete high school or junior college. This age is steadily rising as the output per man per hour increases. "The boy or girl under eighteen who works, keeps a man or woman out of a job." Only a war emergency will lower the age. How many candidates for plant work today will have only the "ability to read, write, and make rudimentary calculations" of which Mr. Matson speaks (*3*)? Today one rarely meets "alertness, carefulness, and conscientiousness" coupled with educational deficiencies. But boys of mental keenness will rarely be satisfied with routine jobs unless they have definite avocational activities. "If the worker can be shown why his own operation is important and what happens if wrongly performed, he will be a more efficient worker and more contented—not in the sense of being submissive about wages but as a harmoniously functioning individual" (*5*).

Well-informed employes avoid industrial risks (*6*). Teaching safety to an uninformed workman is not enough. The employe must have correct technical information. Companies like Westinghouse, which demand a growing employe and encourage his growth, are more liable to maintain high morale than those who do not.

The avenues of instruction for advancement are fairly adequate for the ambitious boy with real scientific ardor. The "credit hound" soon betrays himself. A high-school graduate can better prepare himself by a nine-month intensive course for chemical employment than a grade-school boy in two or three years. The "new leisure" should provide for scientific as well as artistic and literary diversion. How many communities really provide for the assistance of the boy or young man with the cellar or attic laboratory (*7*)?

The young technician, like the young engineer, should be well grounded in the fundamentals of mathematics and the sciences (*8*). He should not only be technically efficient but should be acquainted with the social and scientific basis of his work, be able to plan for himself, have an insight into the social bearings of his plans, and able to readjust himself to changing conditions. "The industries . . . have failed or are failing to educate their employees. . . to make the most of themselves. . . and the properties for which they work.". . . "There is a vast difference between carrying out the plans of others in one's immediate work and efficiency in forming one's own plans with an insight into their social bearings.". . . "A vocational education is to be promoted. . . which utilizes the scientific and social factors of the present system to develop an intelligence that is courageous, practical, and executive" (*5*).

The boy incapable of mastering the fundamentals of science and mathematics is poor material for employment in either plant or laboratory. The technical high school and the trade school hope to salvage hand-minded boys—half of them—who seek refuge from the academic schools.

Chemistry is not an aristocratic science. Its patron saint is Faraday who began as a lab boy. There is real reason to believe that chemical companies may have a place for the non-college man (*9*) who comes in at the bottom, that such men can still emerge, and that they should receive encouragement to do so. If the chemical engineers are concerned about their prospective students and graduates, some one must speak for those who serve in a humbler capacity and who lack funds or encouragement to get further technical education except while they earn. One disagrees that ninety-nine out of a hundred plant employes must be doomed to hopeless mechanical drudgery. Such a philosophy confuses man and the machine. The chemical industry cannot afford to employ drudges or dull people who press the wrong button or close the correct valve at the wrong time. There is a need to train and educate high-type boys for jobs on the middle level as well as the upper levels of industry.

Let us then, as Dr. Rogers suggested, appeal to the Chemical and Process Industries:

(*A*) To establish scholarships and fellowships for deserving employes much as the Salters Institute of London (*10*) establishes Grants-in-Aid up to twenty pounds per year "to young men and women, employed in the chemical works in or near London, who deserve to extend their knowledge for a career in Chemical Industry." The steady upgrading of each employe to his mental saturation point cannot fail to be of advantage to far-sighted chemical companies.

(*B*) To secure the real coöperation of the large companies in providing facilities for such upgrading close at hand.

(*C*) To standardize correspondence and extension work so as to be of greater value to those too far away from major chemical centers to secure direct training from chemical institutes and night schools.

(*D*) To secure closer relations between correspondence schools and existing night schools (the Benton Harbor plan) to aid ambitious employes.

(*E*) To coöperate in any such survey (*11*) as that

of the Chemical Engineers which will secure data concerning the technician as well as the graduate chemist or chemical engineer. The interests of the humbler workers should not be forgotten.

The Division should empower this Committee to make such an appeal as Dr. Rogers suggested to the chemical and process industries or make it through the Council. The Committee should keep its organization (*a*) for guidance purposes and (*b*) to collect and publish comments from chemical firms and teachers. The careful consideration of the Division is requested, with action at an early date, if possible.

The addenda of the original report contained quotations from the Universal Oil Products pamphlet No. 98 (*3*) concerning "The Human Element" and "Inspection"; an Associated Press article from the *Philadelphia Evening Bulletin* of December 24, 1931, concerning scientific research by employed youth in Germany, quotations from the Bulletin of the Salters Institute of London concerning their objectives, the administration of their grants-in-aid and their advisory work; quotations from the Franklin Institute Bulletin (Boston) entitled "From No Man's Land to Leadership"; and "Values Derived from High School Ceramics" by Arnold Bookheim,[1] giving aims and outlines of the course of study in a high-school ceramics course. Character qualities, good work habits, ceramic information and interest are emphasized in this last.

The Franklin Institute Report states from its survey that employers feel that the human material as it comes to them cannot grow unaided to meet the situation which continually confronts it in their plants. They feel that "to meet change" young workers must have "technical insight" and "willingness to take responsibility" and that there is a need for a supervising force of men who reason from cause to effect; who apply the principles of technology and science; who comprehend them and transmit them to skilled and non-skilled workmen; in short, who are the "class room teachers" for the entire force, and the corner stone of its morale.

[1] BOOKHEIM, *Bull. Am. Cer. Soc.*, **13**, 271 (1934).

SOURCES OF DYNAMIC LEADERS

"The Army tests were designed to measure capacity for leadership. The A and B grades were set so as to include the highest sixteen per cent. of the entire population regardless of education or background. The number of men with college background who scored A or B on the test was determined and also the number who made the same score but who had never entered college. The ratios to the total number in each group were then determined.

"If we apply the ratios thus determined to the population at school, in the United States probably 60,000 young men of A and B grade enter college each year, forty per cent. of those who enter college. It appears that the number of A and B grade boys who do not enter college is about 140,000, thirteen per cent. of the entire group. The number is large because of the great size of the non-college group. Seventy per cent. of all A and B grade boys and young men are found in the non-college group."

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An ATOMIC WEIGHT DETERMINATION *for* HIGH-SCHOOL STUDENTS

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(1) This article describes an experiment in the determination of atomic weights for high-school students; the need and purposes of such an experiment are pointed out. (2) Certain criteria for a quantitative experiment to be done by high-school students are proposed. (3) A table of typical results obtained by students is presented.

THE teacher of high-school chemistry often feels a need for a simple experiment which will illustrate to the student the meaning of atomic weights. The atomic weight of some particular element may become a real and significant thing to the elementary student if he has had actual experience in the quantitative determination of the atomic weight of that element.

To be suitable for the use of high-school students any experiment which proposes to be quantitative in nature should have at least the following qualities.

(1) It should involve a minimum of technic and experience on the part of the student.

(2) The apparatus and reagents required should be those found in most high-school laboratories.

(3) The experiment should not require more time for completion than the average laboratory period affords.

(4) The method should be one which consistently gives fairly accurate results.

(5) There should be no element of danger to the student in the performance of the experiment.

Since atomic weights are usually expressed relative to the oxygen atom, it seems that the synthesis of a binary oxide affords the most desirable type of experiment for the illustration of atomic weights. Methods of direct synthesis—magnesium oxide for example—are described in various laboratory guides. There are several objectionable features to the use of the direct method for high-school students; hence, we have resorted to an indirect method of synthesis. A number of laboratory manuals, high-school and college,[1] describe an indirect method of oxidizing such metals as tin, copper, and so forth, with nitric acid. The writer has not encountered a manual which describes the method of indirect oxidation of copper as applied to a determination of atomic weights, however. Herewith is presented a description of such a method.

A weighed quantity of copper turnings in a crucible is dissolved in concentrated nitric acid, added drop by drop, until action ceases. The resulting copper nitrate is slowly evaporated with a very small flame. Heat is further applied until the copper nitrate is decomposed into the black oxide of copper. The evaporation and decomposition should be done with care to avoid the loss of materials by spattering. The reaction between the nitric acid and the copper must be done in a fume hood or under some other condition where the oxides of nitrogen can be removed; many teachers may prefer decomposing the copper nitrate in a hood also. The black oxide of copper should be heated strongly to constant weight to insure complete decomposition of the nitrate. The crucible is then cooled to room temperature and weighed to an accuracy of one-hundredth of a gram.

[1] HOLMES, "Laboratory manual of general chemistry," 4th ed., The Macmillan Company, New York City, 1937, pp. 77–8.

The following are student values with the atomic weights of copper found.

TABLE 1

Student No.	*Grams of copper used*	*Grams of copper oxide formed*	*Atomic weight of copper*
1	1.20	1.48	68.5
2	2.88	3.45	80.8
3	1.41	1.74	68.4
4	1.03	1.31	58.9
5	1.32	1.64	66.0
6	1.44	1.77	69.8
7	1.67	2.05	70.3
8	1.20	1.50	64.0
9	0.90	1.12	65.5
10	2.64	3.29	65.0
11	1.59	1.96	68.8
12	1.70	2.13	63.3
13	1.85	2.28	68.8
14	1.65	2.10	58.7
15	1.18	1.54	52.4
16	1.71	2.10	70.1
17	1.68	2.11	62.5
18	1.22	1.58	54.2
19	1.45	1.83	61.1
20	1.45	1.77	72.5
		Average	65.5

(Accepted value 63.6)

The following is a sample of the calculations done by the student. The data are those of student No. 10.

Wt. of copper used..... 2.64 g.
Wt. of copper oxide formed..... 3.29 g.
Wt. of oxygen used..... 0.65 g.

Since

Wt. of copper used : Wt. of oxygen used = Comb. wt. of copper (referred to O = 16) : 16 g. oxygen.
By substitution,

$$2.64 : 0.65 = \text{Comb. wt. of copper} : 16$$

$$\text{Comb. wt. of copper} = \frac{16 \times 2.64}{0.65} = 64.98$$

(The student's value to one decimal place is 65.0)

Some objectionable features of this method are that the inexperienced high-school student has to handle concentrated nitric acid; besides, the nitrogen oxides are poisonous. By taking due cautions, however, these dangers can be obviated.

Some advantages which the choice of copper in this method seems to possess are the following.

(1) Copper turnings are inexpensive and would be more commonly used in the average high-school laboratory than such a metal as tin.

(2) Copper turnings dissolve in nitric acid readily.

(3) The combining ratios give the "true" and not the "apparent" atomic weight when copper is used.

(4) Copper is suitable for demonstration and explanation of how the atomic weight of an element is found from its specific heat—based on the law of Dulong and Petit; such a demonstration gives the elementary student further insight into the quantitative aspects of atomic weight determinations.

SYSTEMS *of* ACIDS *and* BASES[1]

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IN QUITE early times chemical workers become familiar with certain volatile materials such as spirit of vinegar or oil of vitriol which in proper dilution changed the color of vegetable dyes, tasted sour, and acted on various metals, earths, and alkalies, often with effervescence. In so acting their sour or acid principle was killed or neutralized and one could often show that the product was a "neutral salt," *i. e.*, a soluble, crystalline substance with a characteristic taste, such as sea-salt or sugar. Later the notion of the "base" (of a salt) was introduced, and this was often a non-volatile residue left when a salt yielded up its spirit or "acid" on distillation. Not only the sulfur acids but also their anhydrides were recognized as acidic as were also, for example, fixed air (CO_2) and oxymuriatic acid (Cl_2) while bases included other earths beside the alkalies and also spirit of hartshorn.

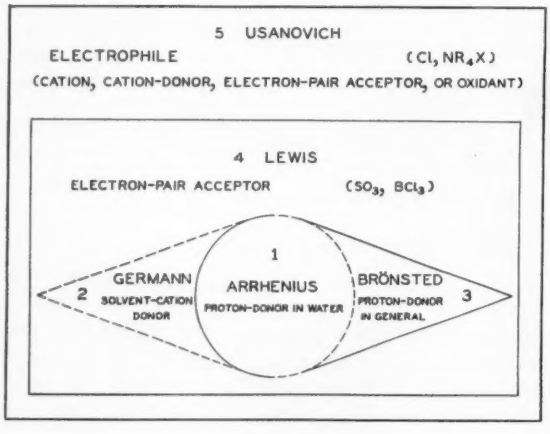

FIGURE 1

The most important early *theory* of acidity is due to Lavoisier, who was encouraged by his studies of oxygen and of chemical composition in general to postulate that all acids were compounds of what he called an acidifiable base (an element such as S or P) with the acidifying principle which was oxygen. Many of the best chemists became convinced adherents of this theory, and it required many years and repeated attacks before it was abandoned. Its opponents successfully showed that (1) many acids contain no oxygen (HCl, H_2S, Cl_2), and (2) many binary oxygen compounds are not acids (K_2O, CaO, and so forth). One reason for the fall of this theory was apparently that it was unduly *restrictive*, in attempting to tie up acid character with the presence of a *single element*. (Also of course, Lavoisier's choice of oxygen was unfortunate.)

A sturdy rival of Lavoisier's oxygen theory was the *hydrogen* theory of acids, which is still widely held today. This theory may be stated as follows: "An acid must be a hydrogen compound, but not all hydrogen compounds are acids." Both the Arrhenius or electrolytic dissociation theory formulation of the acid-base problem (which I will sometimes call the water-ion theory) and the Brønsted-Lowry point of view are forms of this hydrogen theory of acids. This view has, however, been rejected by many chemists. Even Humphry Davy whose work did more than any other to displace the oxygen theory by the hydrogen theory of acids, wrote in 1814 "that acidity does not depend upon any particular elementary substance, but upon peculiar arrangement of various substances." Among modern opponents of the hydrogen theory may be listed A. F. O. Germann,[3] M. Usanovich,[4] and especially G. N. Lewis.[5]

Berzelius, who had adopted a modified form of the oxygen theory, in that he regarded all acids as oxides of non-metals, of all bases as oxides of metals, was also the first proponent of the dualistic electrochemical view which was revived by Kossel[6] and whose modern developments are also seen in the work of Germann, Usanovich, and Lewis.

Berzelius could not properly appreciate the force of the hydrogen theory as advanced and supported by Liebig, and clung to the oxygen theory to the end of his life. In spite of his authority, however, the hydrogen theory slowly gained ground, and, helped simultaneously by the growth of structural organic chemistry and by the increasing importance in inorganic chemistry of reactions in water solution, it secured and still holds today an almost universal acceptance.

THE WATER-ION SYSTEM

Without retracing all the intermediate steps we may

[1] Contribution to the Symposium on Theories and Teaching of Acids and Bases conducted by the Divisions of Physical Chemistry and Chemical Education at the ninety-seventh meeting of the A. C. S., Baltimore, Md., April 4, 1939.

[2] I am greatly indebted to Mr. Fred Meyer for helpful discussion during the preparation of this paper.

[3] GERMANN, *J. Am. Chem. Soc.*, **47**, 2461 (1925).

[4] USANOVICH, *J. Gen. Chem. (U. S. S. R.)*, **9**, 182 (1939).

[5] LEWIS, "Valence and the structure of atoms and molecules," Chemical Catalog Co., New York City, **1923**; "Acids and bases," *J. Franklin Inst.*, **226**, 293–313 (1938). See also *J. Am. Chem. Soc.*, **61**, 1886, 1894 (1939).

[6] KOSSEL, *Ann. Physik*, **49** (4), 229 (1916); *Z. Elektrochem.*, **26**, 314 (1920).

now state the water-ion form of the hydrogen theory which the success of Arrhenius' ionic ideas has brought into widest use today.

Definitions

An *acid* is a hydrogen compound which in water solution gives hydrogen ion, a *base* is a hydroxyl compound which in water solution gives hydroxyl ion.

(*Note:* CH_4, SO_3, and $SnCl_4$ are not acids; K_2O, NH_3, and C_2H_5OH are not bases.)

Acidity and *alkalinity* are restricted to water solutions and refer to an unbalance in the concentration of the solvent ions (*i. e.*, HCl dissolved in toluene is not acidic, nor is pure H_2SO_4; neither fused KOH nor a solution of sodium amide in liquid ammonia is alkaline).

(*Note:* The operational meaning of "hydrogen-ion concentration," and so forth, may be readily stated in terms of indicator colors, E.M.F. and conductance measurements, catalytic activity, and so forth.)

Corollary

Certain ions such as HSO_4^- or NH_4^+, $MgOH^+$ or $BaOH^+$ may be acids or bases on this view—only hydroxyl compounds may be amphoteric.

These definitions are clear and self-consistent, are perhaps adequate to the needs of many beginning students of chemistry, and have permitted the formulation of the relative strengths of many water-soluble acids and bases in terms of their so-called ionization constants. They have, however, been attacked from various points of view.

THE GENERAL SOLVO-SYSTEM

In the first place it has been pointed out that water, while a most exceptional solvent, is by no means unique, either in its self-ionization or in its power to dissolve acids, bases, and salts, and to serve as a vehicle for their interactions. E. C. Franklin[7] in particular has stressed the profound similarity between reactions in water and in liquid ammonia and has pointed out that parallel to the aquo-system of acids, bases, and salts related to water, there exists an ammono-system of substances similarly related to ammonia. Thus, while the strong acids dissolved in water exist principally as oxonium salts OH_3^+, X^-, in ammonia they exist as ammonium salts NH_4^+, X^-. Corresponding to K_2O and KOH in the water system, we have K_3N, K_2NH, and KNH_2 as alkalies in the ammonia system. Aminomercuric chloride is an ammono-basic salt as MgOHCl is an aquo-basic salt. This point of view has been applied with varying success to many of the hydrides as parent solvents. Thus hydrazine, hydrogen fluoride, hydrogen sulfide, and even methane have been made the basis of similar systems. In each case, parallel to the self-dissociation of water

$$2H_2O \rightleftarrows H_3O^+ + OH^-$$

there is a corresponding self-dissociation of the other solvent, such as

$$2NH_3 \rightleftarrows NH_4^+ + NH_2^-$$

and the conceptions of acidity and alkalinity may be logically extended to solutions in each solvent where the lyonium[8] and lyate[8] ions are active.

All the solvents mentioned above are hydrides, but there seems no reason why the nomenclature should not be extended to others as well. Thus, Walden,[9] Jander,[10] and others have ascribed acid-base character to reactions in the solvent SO_2, which is supposed to dissociate as follows.

$$2SO_2 \rightleftarrows SO^{++} + SO_3^=$$

Germann[3] has pointed out that phosgene ($COCl_2$) may be regarded as the parent of an acid-base system. Here, however, the dissociation presumably takes the form

$$COCl_2 \rightleftarrows CO^{++} + 2Cl^-$$

or

$$COCl_2 \rightleftarrows COCl^+ + Cl^-$$

Acids in these solvents do not contain or liberate protons, but other cations instead. The latter author has explicitly given the most general formulation to this point of view.

We have thus been led a long distance, both from the traditional, pre-Arrhenius view and also from the highly restricted water-ion system, and many are ready to cry, "Halt!" at this point. Opposition to the general solvo-system may be summarized under these heads.

(1) Many feel that while it may have formal merit, the practical importance of non-aqueous systems is too slight to warrant giving up the more specific and familiar water-ion system.

(2) Others feel that when we abandon the hydrogen theory of acids, the system becomes too general to be useful—that there is something intrinsically and exclusively acidic about hydrogen compounds, not shared by non-hydrogenic lyonium salts.

(3) A third group would hold that the theory is not general enough. In tying up acid-base behavior to particular individual solvents it ignores the widespread feeling that certain substances such as SO_3 and NH_3 are acidic or basic in their own right, irrespective of the presence of any solvent and so is no better in this respect than the water-ion theory. Such critics would feel that the solvo-system is too much an empty formalism which fails to emphasize the essential underlying mechanism of acid-base action.

Whether for these or for other reasons, the generalized solvo-system has had more lip service than actual use. Elementary texts have stuck for the most part to the water-ion system, and while some research workers have made use of it, much more attention has been paid to

[7] FRANKLIN, *J. Am. Chem. Soc.*, **46**, 2137 (1924); **27**, 820 (1905); also *Am. Chem. J.*, **47**, 285 (1912), and "The nitrogen system of compounds," Reinhold Publishing Corp., New York City, **1935**.

[8] BJERRUM, *Chem. Reviews*, **16**, 287 (1935).

[9] WALDEN, "Salts, acids, and bases," McGraw-Hill Book Co., New York City, **1929**.

[10] JANDER, *Z. physik. Chem.*, **178**, 57 (1936); *ibid.*, **179**, 43 (1937); *Ber.*, **70**, 251–7 (1937); *Z. anorg. Chem.*, **230**, 105; *ibid.*, **232**, 229 (1937).

the Brønsted-Lowry system described below in Lewis' phrase.

"THE CULT OF THE PROTON"

In the year 1923, T. M. Lowry in England and J. N. Brønsted in Denmark independently proposed a novel set of definitions which have aroused wide attention, not only among textbook writers, but among many students of reaction kinetics. As Brønsted has done more than Lowry to develop and use the system, it is now generally known by his name.

Brønsted regards acids and bases as fundamentally different in behavior from *salts*, *i. e.*, electrolytes. *Salts* (which may include acidic and basic ions) are assemblages of ions, and their behavior is essentially described in physical terms as by the theories of Debye, Onsager, and others. Acids and bases, on the other hand, are uniquely characterized by a tendency to exchange protons, and are defined by the fundamental reaction equation

$$\text{acid} \rightleftarrows \text{base} + \text{proton}$$

Here an acid must obviously be a hydrogen compound, but a base may in principle be any substance whatever. Of course in practice only compounds of *labile* hydrogen are acids, and many molecules show no measurable basic behavior. Since the reaction suggested above can occur to a measurable extent only if another proton acceptor is available to compete with the base, the *real* acid-base reactions are always at least as complicated in type as:

$$\text{acid}^1 + \text{base}^2 \rightleftarrows \text{acid}^2 + \text{base}^1$$

Such reactions at equivalent concentrations always run spontaneously in the direction of the formation of the weaker acid and base.

This formulation differs from the preceding ones in many ways.

(1) Acid-base behavior is formally independent of any solvent and not especially related to any, but includes in an unforced way the action of all protolytic solvents.

(2) Ions, instead of appearing as a highly exceptional sub-class, are accorded a status as acids and bases entirely equivalent to that of uncharged molecules.

(3) An acid and a base react, not to produce a salt and a solvent, but to form a new acid and a new base. The conception of the "neutrality" of a solvent loses its meaning.

(4) Acid dissociation and acid solvolysis are seen to be entirely similar phenomena:

$$HCl + H_2O = H_3O^+ + Cl^-$$
$$NH_4^+ + H_2O = H_3O^+ + NH_3$$

as are basic dissociation and basic solvolysis:

$$NH_3 + H_2O = NH_4^+ + OH^-$$
$$C_2H_3O_2^- + H_2O = HC_2H_3O_2 + OH^-$$

(5) Brønsted's system agrees with the others in calling substances like HCl "acids." However, solvated acids such as HCl (H_2O) and NH_4Cl are not themselves acids but salts which *contain* the acids H_3O^+ and NH_4^+, and KOH and KNH_2 are not bases, but contain the bases OH^- and NH_2^-.

(6) Other things being equal, acid strength increases with positive charge and basic strength with negative, but some anions are hardly bases at all (ClO_4^-, RSO_3^-), while many cations (Fe^{+++}, NR_4^+) are definitely not acids, though their hydrogen-containing solvates are in general acidic.

(7) Some substances such as SO_3, BCl_3, and CO_2, which the early chemists would have called acids, are excluded for lack of hydrogen, as are also such things as Germann's "phosgenoaluminic acid" ($COAl_2Cl_5$).

(8) The system is peculiarly adapted to discussing catalytic phenomena of prototropic systems in a variety of solvents,[11] and in principle permits arranging all acids and bases in a single monotonic strength series under all conditions and in all solvents.

(9) The system facilitates a number of instructive comparisons with the system of oxidizing and reducing agents.[12]

The fundamental defining reaction of this system is

$$\text{Reductant} = \text{Oxidant} + n\ (\text{electrons}),$$

and thermodynamic treatment in terms of proton activity, acidity potentials, and equilibrium constants can be applied to Brønsted acids and bases in exactly the same way as to redox systems, except that here electron activities must be used.

(1) The fact that a substance is a strong acid by no means prevents its being also, under other circumstances, an active base. Thus the cations of fluoronium and nitronium perchlorates H_2F^+ and $H_2NO_3^+$ are hydrogen ions formed from the bases HF and HNO_3.

For further elaborations and explanations of the system the reader should consult Brønsted's[13] many journal articles in recent years, his textbook of physical chemistry, and also papers by Klages[14] and Schwarzenbach,[15] and the bibliography recently given by Alyea in the JOURNAL OF CHEMICAL EDUCATION.[16]

It might be better in some ways for me to retire from the discussion at this point in favor of the papers which follow and which are to present in more detail the advantages and disadvantages of the Brønsted and Arrhenius systems. I feel, however, that this introductory survey would be very incomplete if I did not now call my readers' attention to still other important proposals which no student of this field can afford to neglect.

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[11] *Cf.*, especially HAMMETT, *J. Am. Chem. Soc.*, passim; *Chem. Reviews*, **13**, 61 (1933).

[12] *Cf.*, LATIMER, "Oxidation potentials," Prentice-Hall, Inc., New York City, **1939**, and GURNEY, "Ions in solution," The Macmillan Co., New York City, **1936**.

[13] *Cf.*, J. CHEM. EDUC., **16**, 535 (1939).

[14] KLAGES, *Z. Elektrochem.*, **39**, 663 (1933).

[15] SCHWARZBACH, *Helf. Chim. Acta*, **13**, 870, 897 (1930).

[16] ALYEA, J. CHEM. EDUC., **16**, 535 (1939).

THE ELECTRON-PAIR SYSTEM

The first or electron-pair system of acids and bases is by no means new, as it was put forward explicitly by G. N. Lewis in 1923 (*i. e.*, in the same year as the proposals of Brønsted and Lowry). However, as this point of view was not further elaborated by Lewis until 1938, and the underlying ideas have been given a very different treatment by Sidgwick,[17] this point of view has received little attention and now appears almost as novel as if it had just been proposed for the first time. Lewis defines an acid molecule, radical, or ion as one in which the normal electron grouping (often an octet) surrounding some atom is incomplete, and can accept for its completion an (non-bonding) electron pair from some other atom. Conversely, a base is a structure which has such an electron pair which it can share with an acid.

Typical acids are: Monobasic—O, HCl, SO_3, $B(OR)_3$; dibasic—H^+, Ag^+, $SnCl_4$; polybasic—NH_4^+, Fe^{+++}, Cu^{++}, $H_4Fe(CN)_6$.

Typical bases are: Monoacidic—NR_3, CN^-, OH^-, ϕ_3C; dibasic—$(C_2H_5)_2O$, $O^=$.

As Lewis points out, these acids and bases are exactly what Sidgwick has called "acceptor" and "donor" molecules, respectively, but Lewis prefers to apply to them the more ancient names.

In this system an acid does not metastasize with a base, but combines with it. Later, rearrangement or decomposition may occur. Thus the acid oxygen atom combines with the base triethylamine to give a stable amine oxide, but the weaker acid CO_2 gives a product with ammonia which must rearrange to carbamic acid in order to be stable. Readers will observe that this system includes all the acids and bases of the Brønsted system and no other bases, while it points out a host of new acids (including most cations) which the Brønsted system does not recognize as such. In one sense, by including such things as SO_3 and $SnCl_4$, it constitutes a return to the "good old days" before the hydrogen theory, when a thing that acted like an acid was called one without asking of what it consisted. On this point Lewis says,[18] "To restrict the group of acids to those substances which contain hydrogen interferes as seriously with the systematic understanding of chemistry as would the restriction of the term oxidizing agent to substances containing oxygen." In this system a primary acid such as SO_3 may neutralize itself by virtue of its basic properties, forming double molecules or polymers. If, then, it is dissolved in a basic solvent such as water, the stronger base displaces the weaker from combination and we have the new product, H_2SO_4. In the presence of more and more water this molecule may add at least two more molecules of the base, but the resulting electrical strain is so great that the system splits off one or two oxonium ions, leaving at last the $SO_4^=$ ion which is purely basic, and may perhaps combine with one or more molecules of the *acid* solvent.

[17] SIDGWICK, "The electronic theory of valency," Oxford University Press, New York City, **1927.**

[18] LEWIS, *J. Franklin Inst.*, **226,** 297 (1938).

It is quite beyond the scope of this paper to develop the interesting and important consequences of this nomenclature, for which Lewis' own papers must be consulted. One apparent disadvantage of Lewis' system is that acids here have different relative strengths depending on the base with which they react, so that no unique order of acid strengths can be formulated. Chemists must decide whether the restriction which in Brønsted's theory makes this possible is a desirable one.

THE "POSITIVE-NEGATIVE" SYSTEM

The last set of ideas in this field to which I wish to direct attention was outlined only last year by a Russian chemist, M. Usanovich,[3] of the Central Asiatic University at Tashkent. Usanovich is, like Lewis, disturbed by the "illogicality" of Brønsted in restricting acid properties to hydrogen compounds alone, but he goes further than Lewis in identifying general electropositive or electrophilic[19] character with acidity, and nucleophilic[19] behavior with basicity. For him, acids

(1) form salts with bases and effect neutralization;
(2) give up (H^+ or other) cations; and
(3) add to themselves anions and free electrons.

It thus appears that oxidation and reduction become in this system a special case of acid-base behavior.

Examples are

$$Na_2O + SO_3 \rightarrow 2Na^+ + SO_4^=$$

(Na_2O is a base because it gives up the anion $O^=$ and SO_3 is an acid because it takes it up.)

$$3(NH_4)_2S + Sb_2S_3 \rightarrow 6NH_4^+ + 2SbS_4^=$$

($(NH_4)_2S$ is a base because it gives up $S^=$, and so forth.)

$$Na + Cl \rightarrow Na^+ + Cl^-$$

(Na is a base and Cl an acid because they give and take an electron.) NR_3H^+ is an acid for Brønsted, while NR_4^+ is not. For Usanovich both are acids because they are cations, and because they will give up cations to bases.

$$NR_3H^+ + OH^- \rightarrow NR_3 + H_2O$$
$$NR_4^+ + OH^- \rightarrow NR_3 + ROH$$

In the inclusion of oxidation-reduction phenomena and reactions between odd molecules in the acid-base system Usanovich has apparently pushed these ideas to their logical limits. In accounting for the origin of acid-base behavior Usanovich essentially returns to the point of view of Kossel[6] which explains the properties of molecules primarily in terms of ionic charges. Also, however, he stresses the importance of "coördination unsaturation"—the ability of an atom to increase its covalence. For him the acid function depends on the presence of a coördinatively unsaturated positive particle and the basic function on a similarly unsaturated negative atom.

Other things being equal the acid or basic property

[19] INGOLD, *Chem. Reviews*, **15** , 225–74 (1934).

of a molecule depends on the charge or polar valence of the atoms present. Usually the effect of the atom of highest valence will be dominant. Hence oxides of low-valent atoms (alkalis and alkaline earths) are predominantly basic, while those of the third and higher groups are predominantly acidic. The corresponding halides are less basic than the oxides for the same reason and so, also, we find $AsCl_3$, AlF_3, and so forth, much more acidic than the corresponding oxides. Of course most compounds may be expected to show some amphoteric behavior, and other influences[20] than ionic charge are involved or ThO_2 would be as acidic as CO_2.

This point of view, unlike Lewis', does not require of the student a detailed familiarity with atomic structure theory, and is therefore apparently simpler to grasp and use. In its formal aspects, it seems more closely related to the ideas previously current, and in its extreme generality it satisfies the logical demand for a thoroughgoing application of electrostatic theory. The original paper must be consulted for explanations, amplifications, and detail.

In summary, a diagram (see page 124) may serve to emphasize certain of the relationships discussed above. The whole group of substances which have been called acids are divided into five regions. Number 1 includes those substances which dissociate in water to give hydrogen-ions. This is the Arrhenius region. Number 2 includes Number 1 and represents substances which give the lyonium ion in any particular solvent. Number 3 also includes Number 1, but only a part of Number 2. It is the Brønsted region and includes all proton donors. Number 4 (the Lewis region) includes the others and in addition all other substances that are electron-pair acceptors. Number 5 (the Usanovich region) includes all the others and, in addition, all other cations, cationoid reagents, and oxidants.

[20] *Cf.*, discussions of ion sizes.

TEACHING *the* NEW CONCEPTS *of* ACIDS *and* BASES *in* GENERAL CHEMISTRY[1]

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NO OTHER portion of the course in general chemistry receives so varied a treatment as the portion dealing with acids and bases and closely related topics, such as neutralization and hydrolysis. Instructors are fairly well agreed in their opinions of what should be presented and how it should be presented in other portions of the course, such as those that deal with valence, atomic, and molecular weights, the structure of the atom, the properties of chlorine, and the uses of nitric acid. But when different instructors come to the study of electrolytes, and especially to the study of acids and bases, there is a sharp division of opinion. Some believe that acids and bases should be treated entirely from the point of view of the classical theories of Arrhenius and Ostwald. Acids ionize when dissolved in water, or certain other solvents, to liberate hydrogen ions or protons; bases ionize to liberate hydroxyl ions. Frequently, the newer ideas are presented very briefly, and the student is left with the impression that there may be some basis for them, but as yet they are untried and not very useful. Other instructors either omit the classical concepts or pass over them very briefly. They prefer to accept the Brønsted-Lowry concept of proton-transfer as the sole basis upon which the student is asked to understand and explain the behavior of acids and bases. A few instructors may adopt the more generalized classification of G. N. Lewis.

The writer believes that there is still a third method of approach and procedure in teaching this subject. It is not claimed that this method is new. No doubt many instructors use it. It is based upon the principle that the student must first know the facts concerning the behavior of acids and bases, and that facts are of far greater importance than all the theories that have ever been formulated. With the facts before him, the student can then examine critically *all* the theories that have been offered to explain the chemical characteristics and reactions of acids and bases.

We must not lose sight of the origin of theories or of their proper place and use in the science. No theory is perfect. If it were, it would not be a theory. A theory serves its purpose only so long as, and to the extent that, it is useful. Does it offer a reasonable and successful basis for the correlation and integration of

[1] Contribution to the Symposium on Theories and Teaching of Acids and Bases conducted by the Divisions of Physical Chemistry and Chemical Education at the ninety-seventh meeting of the A. C. S., Baltimore, Md., April 4, 1939.

facts and for future work on the problem with which it is concerned? Is it, in short, a satisfactory working hypothesis which we can use to guide and shape our studies until we have more complete information and can build a better theory, or, perhaps, attain the final truth? For the students of general chemistry, a theory must serve the same purpose that it offers the graduate student or the independent scientist. It must serve as a reasonable basis for the understanding and correlation of the many facts and observations which they study in the text, and in the classroom and laboratory.

Some of the difficulties that we find in our general chemistry classes may arise from the confusion of facts and theories. Students are inclined to accept theories on an equal basis with facts. It appears to the writer that this danger may be lessened if the student is made to understand that more than one theory has at different times been offered to explain the same body of knowledge. Perhaps the real danger lies in teaching a single theory as the perfect solution of all the problems with which that theory is concerned. When this procedure is followed, the student may lose sight of the real meaning and the proper place of the theory in the science that he is studying.

The writer believes, therefore, that in presenting a new subject, such as acids and bases, the student should study first the properties and behavior of these substances, not theories concerning their chemical character, or theories concerning the manner in which they react. In approaching the study of acids and bases, the student should be acquainted first with such information as can be provided on his level concerning the properties and constitution of electrolytes as distinguished from non-electrolytes. It is assumed, also, that he will be acquainted, at least in an elementary fashion, with modern knowledge concerning the atom and interpretations of atomic structure that are based upon this knowledge. He will also know something about the differences in properties of heteropolar and homopolar compounds; electrical conductivity of solutions; electrolysis and Faraday's laws; the vapor tensions, boiling points, freezing points, and osmotic pressures of solutions; and the abnormal behavior of electrolytes. We have mentioned here some of the information that will have been provided before the student finally comes to the study of acid-base equilibria.

The student is now ready to examine the theories that have been proposed to explain the behavior of electrolytes in general, and acids and bases in particular. The writer does not believe that the thorough presentation of Arrhenius' theory can be disregarded at this point, or that to follow its presentation with the new concepts is inconsistent with good teaching. We can say to the student that here are the facts as Arrhenius knew them in 1887, and here is the theory that he based upon these facts. But we shouldn't stop at this point. We should also ask the student to examine the facts and the theory. Does this theory explain all the facts? Is it the only theory that Arrhenius might have offered to explain the facts? Furthermore, is the state of our knowledge on this subject no further advanced than it was in 1887? Or have we discovered other information that makes possible a better, more satisfactory explanation? And here, it may be said, is an opportunity for really effective teaching; an opportunity to develop in some small measure, at least, a critical attitude. Was it necessary for Arrhenius to assume that all electrolytes, except at infinite dilution, are only partially ionized? Was his assumption that the electrical conductance of a solution depends only upon the concentration of the ions and that the velocity of the ions is independent of the concentration either necessary or justified? Let us be even more critical. How does his theory explain the heats of reaction of strong acids and strong bases? Is it consistent with modern knowledge of the crystal structures of salts like sodium chloride?

The student, himself, will find many other difficulties that stand in the way of his complete acceptance of the theory. He may ask why hydrogen chloride, which is a non-conductor in the pure state, should become a very excellent conductor when it is dissolved in water but not in benzene. He will not be satisfied by the answer that in the presence of water some of the molecules of hydrogen chloride dissociate into electrically charged atoms of hydrogen and chlorine, and other molecules do not. The ideas of equilibrium and reversibility do not help a great deal. Even with their help, he must still wonder why ions that once separate should combine again under the same conditions. If hydrogen chloride were a heteropolar compound, as sodium chloride is, the effect of the water dipoles might help somewhat. Even then, however, he might still wonder how water dipoles could bring about the separation of ions and at the same time allow the same ions to recombine. When he turns his attention to the solvent, water, in which the hydrogen chloride dissolves, his wonder and amazement may be still more increased. For here is a substance that, although a very feeble conductor, must produce a few ions. How is it different from hydrogen chloride which apparently produces no ions? Certainly here, as elsewhere, Arrhenius' theory offers a very unsatisfactory explanation of the production of ions in the presence of water molecules.

If the classical theories of electrolytes are thus critically examined, how can we justify the elimination of the new concepts? Surely it is not inconsistent with good teaching to have the students know that other explanations have been offered to modify and to replace the ideas that came into general use in 1887. Why should we acquaint the student with modern concepts of atomic and molecular structure, if it is not to offer a reasonable and satisfying basis for the understanding of such subjects as valence, the periodic classification of the elements, atomic weights, and the differences in properties of heteropolar and homopolar substances? Having done all this, why stop short of using this same background of understanding as a basis for explaining the ionization of electrolytes and the reactions of ions?

Should the student of general chemistry become acquainted, therefore, with the Debye-Hückel theory and

the concept that substances which crystallize in ionic lattices are completely ionized in solution? Should he study the Brønsted-Lowry concept that bases remove protons from acids and that a substance is an acid and may act as an acid regardless of whether or not it is in aqueous solution? Should he be offered the suggestion that the acid does not first ionize independently to liberate free protons? These questions must be answered from the student's point of view. If they provide a more reasonable and satisfying explanation for the facts that he studies and the observations that he makes, then they should be made available to him. The writer believes that, when the problem is viewed in this light, there can be no doubt as to the answer.

The presentation of more than one theory to explain the same group of facts may be argued by some to result in confusion in the minds of students. The writer wishes to state his opinion that there can be no confusion if we teach facts rather than theories, and if theories in general chemistry, as well as elsewhere, are made to serve only the purpose for which they are built. Different theories can become confusing when they are studied and taught as worth-while and important ends in themselves, and quite apart from the facts that they attempt to correlate and explain. The beginning student in science should develop a critical attitude. His instructor must make sure that he does not accept the first explanation that is offered as an ultimate truth, always to be revered, never to be questioned. The writer knows of no better way to develop the questioning attitude of science in the minds of students than by leading them to examine freely and openly *all* the suggested explanations and solutions of a given problem, especially when we admit that the problem has not yet been completely solved. If one of the functions of the teacher of science is to develop in his students this critical attitude, then surely this teacher must welcome the opportunity that comes his way in teaching the subject of ionization and especially the chemistry involving acids and bases. Surely our students, even with their limited experiences, can be expected to study, compare, and criticize two theories as simple as the Arrhenius-Ostwald and Brønsted-Lowry concepts.

Much has been said and written on the dangers of unlearning. It might be said, for example, that confusion must result from the student's learning the classical concepts of acids and bases only to be told that they are now regarded as unsatisfactory and that newer concepts must be learned to take their place. There may be real danger here, but only when the theory is made all-important and comes to be regarded as fact. There is no danger if each theory is examined in the light of the facts that it attempts to explain, and if the usefulness of each theory as an intelligent basis for correlating and understanding these facts is tested sufficiently.

There have been other occasions in the history of science when it has been necessary for teachers and students to consider more than one possible theory, as they have studied and taught certain subjects. As in the treatment of acids and bases, the writer believes that there is a great deal of value in having the student study critically at least some of the older theories as well as the new. The atomic theory of John Dalton has been changed so radically during the twentieth century that some instructors regard its original form as worth only brief mention. The writer believes that it is very much in keeping with the objective of the general chemistry course to have students understand the factual evidence upon which the original theory was based. They should also understand the reasons that lay behind the inclusion of each concept in the theory. Then they should examine the adequacy of the theory as a basis for explaining valence, the reactions of atoms, and the structure of compounds. The need for new concepts will not be difficult to establish. It will then be time to present the relatively new knowledge of radioactivity, of electrons, of isotopes, and of the many other elements of twentieth-century chemistry and physics. Finally, the modern theory of the atom can be presented. Needless to say, this theory must be compared with Dalton's, and it, too, must be subjected to the tests used previously in the examination of the older concepts. The treatment here outlined is the same treatment that is recommended for the study of acids and bases and for the properties of electrolytes in general.

Where shall we use the new concepts of acids and bases in the general chemistry course? Wherever the student finds that they provide a useful and reasonable basis for his interpretation of facts and of observations made in the laboratory. Certainly use will be found for them in the study of the ionization of acids and bases, of the reactions occurring between these two classes of substances, of the theory of indicators, of titration, and of hydrolysis. Perhaps it may be necessary to extend and modify somewhat the work that the student does in the laboratory. We might add, for example, an experiment such as that described by Flowers,[2] in which a solution of sodium acetate in glacial acetic acid is titrated against a solution of perchloric acid in the same solvent with basic fuchsin as the indicator. At least such experiments might show the student that there is need for the new classification of acids and bases and might emphasize the fact that chemical changes are not restricted to aqueous solutions.

[2] FLOWERS, J. CHEM. EDUC., **13**, 219 (1936).

The THEORY *of* ACIDS *and* BASES *in* ANALYTICAL CHEMISTRY[1]

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THE subject of inorganic analytical chemistry can be presented as a series of unconnected empirical procedures; as a practical art instead of a branch of science. The position that it should be taught in this way has, however, been difficult to defend ever since Ostwald showed how brilliantly the Arrhenius theory of ionization illuminated the meaning of the practices which empirical investigation had developed. It has now few supporters, and the dual principle that the theory of ionization is the best way of understanding analytical chemistry, and that analytical chemistry offers the best introduction to the theory of ionization is generally accepted.

Granted that analytical chemistry and the theory of ionization should be taught together, the next question is, what theory of ionization? The original theory of Arrhenius, modified according to Bjerrum and Debye for the case of strong electrolytes, is competent to account for all of the phenomena of the classical inorganic analytical chemistry of aqueous solutions; most of us who are teaching analytical chemistry now were brought up in it; it is comfortable and familiar and therefore seems easier than the proton transfer theory of acids and bases, the modification which we are now urged to adopt; and the need for the new theory has arisen from the study of the kinetics of acid and base catalyzed reactions and the properties of non-aqueous solutions, phenomena which seem to have little to do with analytical chemistry. Why then, runs a common argument, should we alter our instruction to include the new theory?

This would be a good argument if analytical chemistry stood alone and independent of the rest of chemistry, a means and an end in itself. But this is not so; analytical chemistry is a part of chemistry, and instruction in analytical chemistry is part of a curriculum whose aim is to impart the maximum understanding of chemical phenomena. Given two theories, both satisfactory for analytical chemistry, there can be no question that the one which is most generally useful in chemistry as a whole is the one we should teach. Any other choice points toward a sterile classicism which is dangerous both for the future of analytical chemistry and for the future of the science as a whole.

There can be little doubt which is the most useful theory, for the Arrhenius theory can take account only of reactions in a single solvent, which is, of course, always water, and only of equilibrium systems in that solvent. The proton transfer theory, on the other hand, can tell the beginning student why hydrogen chloride and sodium chloride are so much alike when they are dissolved in water and so different under any other conditions. It can offer the organic chemist the opportunity of explaining why he uses sulfuric acid or zinc chloride or sodium amide as condensing agents in one or another reaction. I hope it points toward the day when our physical chemical theory is so good that an organic chemist cannot afford, as he now can, to be ignorant of it.

Indeed one can hope for advances in analytical chemistry itself if we can escape from the vicious circle which trains analytical chemists only in the theory of dilute aqueous solutions because this is the field of analytical chemistry and consequently sees to it that this remains the only field of analytical chemistry. We have already seen[2] a new and valuable analytical method for the determination of amino acids grow out of Conant's and Hall's theoretical investigations of acid-base systems in the solvent acetic acid, and there is every reason to expect that analytical chemists properly trained in theory will develop many more methods utilizing non-aqueous solvents. The possibilities of sulfuric acid, sulfur dioxide, ammonia, or hydrogen fluoride are so far absolutely untouched.

The teaching of an adequate but limited theory in an elementary course might be justified if it were really simpler and more readily assimilable than the more general theory. There is, however, no evidence in my experience that this is the case, and I have taught both theories. Of course, the new theory is difficult to those of us trained in the older theory, but the difficulties we meet do not exist for students who have never met the older theory. Even now my own tongue stumbles over the new terminology, while it slips glibly off the lips of my students, both undergraduate and graduate; but I lived fifteen years with the old theory and the old names before I met the new ones, and the habits of fifteen years are hard to break.

There are even some ways in which phenomena important in analytical chemistry can be more simply presented in terms of the new terminology than was ever possible with the old. If, for instance, one establishes

[1] Contribution to the Symposium on Theories and Teaching of Acids and Bases conducted by the Divisions of Physical Chemistry and Chemical Education at the ninety-seventh meeting of the A. C. S., Baltimore, Md., April 4, 1939.

[2] NADEAU AND BRANCHEN, *J. Am. Chem. Soc.*, **57**, 1363 (1935).

the idea that the term acid includes ions like ammonium ion as well as neutral molecules, that the term base also includes ions as well as neutral molecules, and that any conjugate acid-base system comes to an equilibrium with the solvent, thus

$$\text{Acid} + H_2O \rightleftharpoons \text{Base} + OH_3^+$$

$$\frac{[\text{Base}][OH_3^+]}{[\text{Acid}]} = K_a$$

only a few words are required to account for all the properties of indicators and of buffer solutions, and to lay the foundation for the discussion of acid-base titrations.

Thus an indicator is a conjugate acid-base system in which the color of the acid and base are different. The acid may be neutral and the base a negative ion as with *p*-nitrophenol, the acid may be positively charged and the base neutral as with aminoazobenzene, or the acid may be a singly charged negative ion and the base a doubly charged one as with phenolphthalein; in any case

$$\frac{[\text{Acid}]}{[\text{Base}]} = \frac{K_a}{[OH_3^+]}$$

Consequently a colorimetric determination of the ratio [Acid]/[Base] in a solution of known pH measures the value of K_a, and, with this known, a colorimetric measurement in any solution determines the pH of the solution. A number of obvious corollaries follow. At the half-way point in the color change, *i. e.*, when [Acid] = [Base] then $[OH_3^+] = K_a$ and pH = pK_a. The range of usefulness of an indicator is the region of pH on either side of the value of pK_a for which neither [Acid] nor [Base] is too small for measurement. This is about all one needs to know about indicators in order to use them; the next refinement would be to consider the effect of the ionic strength of the medium on the value of K_a, an effect which differs according to the charge type. The question why the acid and base have different colors is an interesting problem in organic chemical theory but has nothing to do with the use of the indicator.

Similarly, a buffer solution is a solution containing an acid and its conjugate base both at relatively high concentrations. It may be of the type of NH_4^+ plus NH_3, of acetic acid plus acetate ion, of $H_2PO_4^-$ plus $HPO_4^=$ or any other. In any case

$$[OH_3^+] = K_a[\text{Acid}]/[\text{Base}]$$

$$[OH^-] = \frac{K_w}{K_a} \times \frac{[\text{Base}]}{[\text{Acid}]}$$

The buffer property depends upon the fact that a small amount of added or adventitious acid or base can only convert a small fraction of the buffer acid to base or vice versa. Consequently it can change the buffer ratio and the concentrations of oxonium or hydroxyl ions only slightly. If the acid is OH_3^+ and the base H_2O, as in a solution of a strong acid in water, the buffer property of resisting change in acidity is present in fact and appears from the equation, although the solution is not usually called a buffer.

It will be noted that these explanations do not involve any mention of hydrolysis, as the older ones did. As a matter of fact hydrolysis as a distinct phenomena vanishes in the new treatment. The hydrolysis reaction

$$NH_4^+ + H_2O \rightleftharpoons NH_3 + OH_3^+$$

is no different in principle from the ionization

$$HC_2H_3O_2 + H_2O \rightleftharpoons C_2H_3O_2^- + OH_3^-$$

and both are described by the same equation

$$\frac{c\alpha^2}{1-\alpha} = K_a$$

with α the fraction hydrolyzed or ionized and K_a the acidity constant of the acid-base system.

In the same way the course of the titration of an acid with sodium hydroxide, with ammonia, or with sodium carbonate may be described by identical equations, the bases being hydroxyl ion, ammonia, and carbonate ion, respectively, in the three cases. This is very satisfactory because it has always been obvious that the three titrations are similar in fact, and we used to have to apologize and say that the similarity was only apparent.

These are only samples drawn almost at random, but they do show that the new theories and terminologies in acid-base theory may simplify rather than complicate the treatment of the most familiar phenomena of analytical chemistry.

The ADVANTAGES *of the* OLDER METHODS[1]

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THE teacher of general chemistry is constantly on the alert for the acquisition of more effective teaching tools in the presentation of the fundamental aspects of the subject. He is ever conscious of the fact that rapid advancements are being made each year in the development of chemistry but, for the time being,

[1] Contribution to the Symposium on Theories and Teaching of Acids and Bases conducted by the Divisions of Physical Chemistry and Chemical Education at the ninety-seventh meeting of the A. C. S., Baltimore, Md., April 5, 1939.

he is prone to disregard the newer ideas and the results of the more significant discoveries. He is so intensely engaged in his everyday task, loaded down with unusually heavy teaching duties, administrative duties, and what not, that it is not possible for him to digest, let alone evaluate, the advances made in chemistry. He is somewhat consoled when he is reminded that he has been pretty successful as a chemistry teacher during the past ten or twenty years or more, as the case may be, that his students have done well in more advanced work, and that he commands a commendable reputation as a teacher, though the content of his general chemistry course has changed very little indeed.

As new texts or revisions of older ones in general chemistry become available the teacher finds them to contain material pertaining to the more recent discoveries and theories. He examines this material with the hope that he will find more effective teaching tools and new points of view for stimulating the student, keeping in mind that the primary purpose of the general chemistry course is to give the student an adequate understanding of the basic principles of the science upon which foundation the more advanced work may be built. But the teacher is more than often dismayed by his findings. He discovers that many of the newer topics are so briefly presented that they appear merely as new names for the student to memorize, and at the same time they offer no contribution whatsoever to the real aims of the course. In other instances he finds the topics to be adequately described, but he hesitates to adopt them. Why? He is not sure whether the newer point of view affords a better method of presentation that that formerly used. He makes an attempt to evaluate the new theory somewhat as follows.

(1) Will the new theory be more or less understandable than the older one to the beginning student?

(2) Will it tend to clarify the subject matter under consideration or will it lead to confusion?

(3) Will it afford a better means for presenting the subject?

(4) Does the new theory offer to the beginning student any real significant advantages over the older one?

(5) Would the best procedure be to first present the classical viewpoint and to then show in a logical manner the scientific development which has taken place to the destination occupied by the more modern concept?

(6) From a practical standpoint would the average beginning student be in a position to appreciate the significance of this development?

(7) If the student were merely introduced to the modern concepts would such an introduction be sufficient for the successful pursuance of the more advanced chemistry courses, where it is understood the modern concepts would be extensively employed? Or, would such an introduction be entirely unnecessary?

(8) Would it be better to adhere to the older definitions for general classroom work and then assign reference readings relating to the modern views for the more able and inquisitive students to peruse?

These and many other questions the teacher attempts to answer. Perhaps he himself is not too well versed in the essential characteristics of the new theories and, accordingly, it is difficult, if not impossible, for him to answer the questions he has proposed. The Brønsted-Lowry concept of acids and bases is unquestionably one of several theories which has come under the scrutiny of the teacher of general chemistry during the past decade or so. After reading a number of excellent reviews and articles dealing with the subject, it is evident that the newer definitions possess many significant teaching advantages, and that every student, beginning or otherwise, should have at least an understanding of their rudiments. But are there any advantages in the older methods of presentation? Perhaps it would be better to state this question in another way, namely, are there any disadvantages to be found in the newer methods? Obviously, both questions should be taken into consideration.

It appears that the older methods used to define acids and bases have much to be commended in regard to simplicity. The new definitions of necessity assume the existence of a hydronium or oxonium ion in water solution. To be sure, the evidence for the existence of some type of hydrated ion is clear and convincing, but when H_3O^+ ion is used consistently it is inherently implied that such a species has been correctly labeled. As a matter of fact we have little if any conclusive evidence for the definite existence of this particular species. It undoubtedly exists along with $H_5O_2^+$, $H_7O_3^+$, and with even more highly hydrated protons. By analogy with the ammonium ion, NH_4^+, H_3O^+ has been intelligently selected, but the picture appears to be an attempt to label more specifically than formerly a species of matter which in water solution is certainly far more complex in nature than the label implies. On the basis of the older method, the simplest symbol possible, H^+, is used merely as a symbol to represent an extremely complex system which, for lack of information, cannot be designated accurately. The student is made to realize that all ions are hydrated in water solution but, on account of our lack of knowledge concerning them, we employ the simplest symbols possible merely as a means for giving the ions names.

One might say at this point that you would certainly label the acid constituent in liquid ammonia the ammonium ion, NH_4^+. True enough, though the ammonium ion itself is also without question ammonated in this medium and probably several other ammonated species exist. But here we do use the simplest known species, the ammonium ion. It possesses a fair stability and it is possible to crystallize ammonium salts from solutions. On the other hand, hydronium salts are not usually sufficiently stable to be obtained from water solution as definite entities.

It should be mentioned at this point that in the presentation of these arguments I am thinking of the beginning student in chemistry, who may or may not have had some high-school chemistry training and who is probably planning on taking more work in the field

in preparation for a profession which demands a fundamental training in chemistry. The student who is taking only one year of chemistry, the general course, should also be considered here.

From transference experiments the relative hydration of ions in water solution may be obtained. If it is assumed that the proton carries one molecule of water, then under similar conditions the chloride ion carries about four, the potassium ion five, the sodium ion eight, and the lithium ion fourteen molecules of water. In each instance the hydration of the ion in question is of considerable magnitude in relation to the proton hydration. But in practically all treatments dealing with the properties of electrolytes in water solution, it is seldom that any attempt is made to indicate the hydration of any ion, excepting the hydrogen ion. It may well be pointed out that the size of the proton, the energy effect accompanying the hydration process, and many other properties designate the proton as an exceptional case, in that these effects are by no means observable to the same extent in the hydration of other ions. But is not the proton exceptional merely in the magnitude of these effects? Is not the type of process the same for all ions and the effect a matter of degree rather than of kind? On the basis of the newer definitions of acids and bases the student invariably gains the impression that only the hydrogen ion is hydrated, since the emphasis is placed at this point, no matter how careful the teacher is in his attempt to avoid conveying this impression. The older method has the distinct advantage in that it does not discriminate, but merely implies that all ions are solvated.

When one studies the properties of acids and of bases in a number of different solvents the Brønsted-Lowry definitions are invaluable. The definitions are broad in scope and not only afford an explanation of the behavior of acids and bases in different media but, as a result, point to new fields of investigation. Franklin knew many years ago that the ammonium ion is an acid and the amide ion, NH_2^-, a base in liquid ammonia. He was also aware of the fact that ammonia itself functions as a base as well as an acid. If he had not recognized these properties it never would have been possible for him to construct a nitrogen system of acids and bases for both inorganic and organic substances, and thereby be led to fruitful investigations extending over a period of approximately forty years. Results of similar investigations in other solvents have also appeared during the past two or three decades. There is no doubt but what the workers in the field of non-aqueous solutions have been aided in more recent years by the newer concepts of acids and bases, but certainly these concepts have not been absolutely essential to the pursuance of this work.

From the standpoint of the beginning student of chemistry, is it desirable that he should know a great deal about the properties of non-aqueous solutions? I think most teachers would agree with the viewpoint that it would be a great accomplishment if the student were adequately familiar with the fundamental aspects of aqueous solutions. There is a marked tendency in the teaching of general chemistry today to make the course more and more *general*, to teach the student a little about everything and not very much about anything. Aside from the usual or what might be called the classical content of the course, the student today comes in contact with colloids, dyes, general organic chemistry, foods, carbohydrates, alloys, petroleum and fuels, photochemistry, the chemistry of synthetic fabrics, and a host of other equally important fields. At the same time there is a marked tendency to reduce the time allotted for the teaching of general chemistry. These two effects have naturally resulted in a reduction of the time spent by the student in an attempt to acquire the fundamentals of the subject, which at one time were considered of the foremost importance. If we are to include in our general chemistry program a treatment of non-aqueous solutions, we shall be pressed more than ever before in an attempt to give the student the training he needs for subsequent work in the field.

If we are not contemplating giving a treatment of non-aqueous solutions, then there appears to be less need for a thorough presentation of the newer definitions of acids and bases, since without applications to non-aqueous solutions, the newer definitions are far less effective. The thorough treatment should come in later courses where the student, supported with sufficient facts of chemistry, would be in a position to appreciate better the significance of the development.

This point leads to a similar one which might be considered as the most serious objection to the teaching of the newer definitions to beginning students. If the student is given a thorough presentation of the newer concepts of acids and bases, he very frequently will be required to translate these definitions into the older ones. He cannot escape this situation. The entire chemical literature of the past one hundred years or more is constructed on the basis of the oxygen system of compounds as originally devised by Lavoisier. Our older concepts of acids and bases are also due to him. A relatively insignificant portion of this literature is devoted to chemical material interpreted on the basis of the newer definitions of acids and bases. If the newer definitions are taught the beginning chemistry student, so must the older ones, if he is going to be in a position to make use of his chemical training. It might be argued that if the student is well versed in the newer definitions he will as a consequence become familiar with the older ones. This is undoubtedly true to a certain degree, but still the student would be forced to cope with both definitions successfully. Such a situation would demand more time and thought on the part of the student and it is not at all beyond comprehension that he would become more confused than enlightened in an attempt to describe one set of definitions in terms of another.

Let us further consider this process of translation. The process is capable of being carried out in both directions; the newer definitions may be translated into the old, and the old into the new. It has already been

stated that once having the newer definitions it would be necessary to convert them into the older ones, as far as the beginning student is concerned. Which process is the more logical and desirable one? If the student were thoroughly acquainted with the older definitions and had some acquaintance with the newer ones, would he not be in the more favorable position?

The development of chemistry and of science in general has been a gradual but continuous process throughout the decades. Facts are accumulated; when a sufficient number of them become available, theories are proposed, which eventually may lead to laws. But the facts are needed first before any generalizations or theories may have any footing whatsoever, since the theories must be in accord with the experimental facts. This development of theory from facts is the very essence of science. Why not permit the student of today, perhaps the scientist of tomorrow, to have the opportunity of experiencing the thinking processes of man in the progress of science? Why have we arrived at these newer definitions of acids and bases? Because chemists have been working with solutions and have been thinking about the problems involved in their behavior for a hundred years or more. These definitions have not emerged suddenly from nothing. The beginning student of chemistry should become acquainted with the thinking processes involved in the development of the theories of chemistry, *for that is chemistry.* That goal would be better realized by first giving the student the older methods of treating acids and bases and then by showing him why the newer methods have been formulated. It seems that this transition process could best be accomplished in the more advanced chemistry courses where the student, fortified with some facts of chemistry, would be in a position to appreciate this unique development. Such a procedure appears to be a logical as well as a desirable one.

What is there that is fundamentally wrong with the older methods for describing acids and bases? Are these methods to be likened, for example, to the Phlogiston Theory of combustion, in that they should be completely discarded as being scientifically incorrect? Certainly not. But one does get the impression that it is rank heresy to deal with the older definitions. They are as accurate today as they ever were and need no apology. The newer definitions include exactly the same facts and lead to the same results, but they express these facts and results in a different language, a new nomenclature, which, as has already been pointed out, possesses certain advantages. Professor A. A. Blanchard, in his recent article entitled "Unlearning"[2] has very ably defended the teaching of what might be called *classical chemistry.* He states, "The enthusiasts for the Brønsted formulation, of course, feel that with one magnificent conception they have embraced all degrees of neutralization, equilibrium, and hydrolysis. They fail to realize that their own ability to appreciate this broad formulation is due to the background of their own slow progress in logical development, which was based first on an appreciation of the significance of the sharp neutralization of the strong acid and strong base. All acids must have some common component to account for the common properties. This component they may have named hydrogen ion, or perhaps, merely hydrogen in the acid state, and the common component of bases they may have named hydroxyl ion, or merely hydroxyl. But whether acid hydrogen or hydrogen ion, their conception was truth, which they should not delude themselves that they have unlearned."

The newer definitions are effective in describing ionic processes, such as the ionization of weak acids and of weak bases, the hydrolysis of ions, and the formation of complex ions, but when equilibrium is attained in such systems both the older and the newer definitions give the same results. This is due to the fact that equilibria are independent of the mechanism of the processes involved in reaching the equilibrium state. If the initial and final states of the system can be defined, what happens in the process of going from one state to the other is of no consequence as far as the final result is concerned. Thus, if we add a molecule of water to one side of an equation, used to express a given reaction, it must also be added to the other side. In other words, the water offers no contribution to the equilibrium. On this basis, it makes no difference whether we speak of H^+ or H_3O^+ in equilibrium considerations, we arrive at the same result. On the other hand, from the standpoint of the mechanism of the ionic reaction, the situation is entirely different. The water molecule enters into the picture, but how and to what extent, again we do not know. The newer definitions of acids and bases provide one picture, which is only a picture, though it is to be admitted it is a useful one for interpreting and predicting the behavior of ions in solution.

The treatment of the hydrolysis of ions derived from weak acids, for example the acetate ion, is relatively simple on the basis of the newer concepts. On the other hand, this same treatment extended to the hydrolysis of ions of weak bases is not so simple. In addition, the treatment given for the ionization of amphoteric hydroxides and bisulfides assumes the formation of highly complex ions the compositions of which are not definitely known. It would be necessary for the student to be well versed in the fundamental aspects of the coordination theory before he could even render a guess concerning the composition of most of these ions, and then his prediction probably would not be correct. The terminology and the equations used to express these ionic reactions are far more complex than those required by the older methods. To the beginning student of chemistry this situation would inevitably be confusing.

On the basis of the arguments herein presented, as well as others which might be cited, it is felt that for the teaching of the beginning student of chemistry a saner program would be to start with the classical definitions of acids and bases and then to present briefly

[2] BLANCHARD, J. CHEM. EDUC., 16, 57 (1939).

the newer ones, after the student has become acquainted with the more basic concepts of chemistry and has acquired some of the essential facts. Then the student would be able to appreciate the significance of the development of the ideas, in much the same manner as all of us have.

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IT IS frequently stated that the honour of being the first school in England to add the study of natural science to its curriculum should be awarded to Rugby, for evidence was given before the Public Schools Commission (1864) that a school of natural philosophy with a specialist teacher had been instituted there as early as 1849 (*1*). In 1859 the work was extended by the construction of a laboratory and physical science lecture room—the cost, one thousand pounds, being, at the time, a very large sum to spend in such a manner. The study of natural science was not, however, obligatory; it was available to the senior boys only, and then as an alternative to modern languages. Nevertheless, the Commission found it possible to report that of the nine public schools it was only in Rugby that the study of natural science was taken very seriously.

Another Commission, the Schools Inquiry Commission, appointed to investigate certain other schools—schools which would be known today as secondary or public schools—reported in 1868, when referring to science (*2*),

> "We cannot consider any scheme of education complete which omits a subject of such high importance,"

but recognized the difficulties in the way of introducing successful science teaching into the schools. In particular, competent teachers were scarce, good elementary textbooks were wanting, and apparatus and laboratories almost non-existent.

It is interesting, therefore, to enquire where science teaching was first introduced. It seems likely that the credit for introducing into the curriculum science teaching of the kind we recognize today can be granted to the Liverpool Institute.

We are told in the biography of Sir Henry Roscoe (*3*),

> "Young Roscoe went for a few years to a preparatory school in the neighbourhood of his home. In 1842 his mother moved her small charges to Liverpool, when he was sent to the High School of the Liverpool Institute, among the earliest of the so-called 'modern' schools. He remained here seven years, taking the usual English subjects—mathematics, French, a little Latin and less Greek, and some elementary physical science. The school was furnished with a chemical laboratory—a very unusual provision in those days—and in it he obtained his first lessons in chemical manipulation from William H. Balmain, the discoverer of 'luminous paint' and of boron nitride. Balmain, who was one of the early contributors to the then newly founded Chemical Society, in his published account of the latter substance apologizes for his inability to state its exact composition, as he was unable to obtain a better balance than such as he could construct himself of wood and paper—a circumstance which throws some light upon the means of instruction in the laboratory which introduced Roscoe to the study of practical chemistry."

A search through some of the documents in the Liverpool Institute, carried out with the kind permission of the Head Master—Mr. J. R. Edwards—led to the discovery of much interesting material dealing with the science teaching given in the Institute during its early years. Before proceeding to an examination of this, however, it must be explained that the Liverpool Mechanics' Institute, as it was then called, was founded in 1825, but that it was not until 1837 that funds were large enough to enable the Institute to be accommodated in premises of its own in Mount Street.

Two schools were established in connection with the Institute, in 1835 a Lower (or Commercial) School, and then, in 1838, a High School. Later an Infants' School and a Girls' High School (Blackburne House) were added, but these are outside the province of the present paper. It seems to have been thought that such institutions would make good use of the Institute's building during the daytime hours and also provide educational facilities of a type which were sorely needed. However, it is not possible to go here into the detailed history of the formation of the schools, but it is worthy of note that eventually, like the great majority of mechanics' institutes, the evening lectures with the library and reading room facilities faded away. Nevertheless, unlike many other institutes

the Liverpool Mechanics' Institute had its schools, two of which, the High School and Blackburne House, have survived to the present day, although they are now, after a transfer which took place in 1905, maintained by the City Council.

The earliest specific reference to the teaching of science is to be found in the Prospectus of the Schools for 1837. Here, under the heading *Philosophical Department*, it was explained that the instruction was to be given by demonstrations, the teacher making use of material from the Museum of the Institution. Clearly, the younger pupils were to be given what are now known as "object lessons," and the examples quoted in the prospectus were a mineral, a plant, a stuffed animal, a specimen of some manufactured fabric, a tool, a piece of furniture, or a model of some simple machine. The program of work in the higher classes appears to have been more ambitious for the course included Mechanics, Hydrostatics, Pneumatics, Optics, Acoustics, Chemistry, Electricity, Magnetism, Geology, and Natural History. It is probable that the instruction in these subjects was not intended to be more than elementary; it is stated "the pupils, when they leave school, will then be prepared for that more extended instruction on these subjects which the public lecture may be expected to afford."

There were six classes in all, and in the Report on the first term's work reference is made to the two lower classes which took an object lesson of one hour's duration each week. The four higher classes were given courses in Mechanics, Geology, Natural History, and Chemistry, the reason for the selection of the subjects being the pupils' weakness in mathematics.

No details are given as to the syllabus followed, nor is it possible to discover the content of any of the courses, but from the Report for 1839, it may be gathered that it was usual to ring the changes in the various subjects with considerable freedom and little apparent coördination. However, in 1841, the following details were given in the Prospectus (*4*):

10-3-1841. IV. THE DEPARTMENTS OF NATURAL PHILOSOPHY AND CHEMISTRY

"In the Natural Philosophy Department, the pupils will be conducted through systematic courses on the following subjects:—

"I. Natural Philosophy—Properties of Matter—Statics—Dynamics — Hydrostatics — Hydrodynamics — Pneumatics—Heat—Electricity—Magnetism—Light and Sound—Mechanics—Meteorology—Astronomy—Steam Engine.

"II. Botany—Vegetable Anatomy and Physiology—Classification of plants—the characters, properties, and uses of the Natural Families of Plants—Exercises on the British Flora.

"III. Zoölogy—The structure, functions, and habits of the leading tribes of the Animal creation—The anatomy and physiology of Man.

"The subjects will be taught in a very popular and elementary style in the junior classes; and in all will be carefully adapted to the capacity and progress of the pupil.

"The method of instruction pursued, will be reading from a textbook, explanations and demonstrations by the teacher, drawings and experiments, and constant examination of the pupils, and of exercises given them to write.

"In the Chemical Department, the pupils will be conducted through systematic courses on the following subjects:—

"I. Chemistry—Chemical Philosophy—Manufacturing Chemistry—Application of Chemistry to the arts; to animal and vegetable Physiology; and to Meteorology.

"II. Mineralogy—Composition of minerals—classification and probable modes of formation.

"III. Geology—Geological reasoning—integral and superficial structure of the Earth—changes which take place in that structure.

"The greater part of the time will be devoted to the science of Chemistry; the other subjects being taken up in each class, at the judgment of the teacher as to the capabilities of the pupils.

"The classes will be taught by experimental and oral demonstrations, with the assistance of textbooks and diagrams; and the progress of each class will be ensured and ascertained by viva voce and written examinations."

In the report for 1843 we read that excellent progress had been made by the pupils in the Chemical Department, and that the sixth and fifth classes had been formed into practical classes under Mr. Balmain. These appear to have been the first *practical* science classes held in a school in this country, and are the ones which young Roscoe attended in his early years. A later report (1844) refers also to cranes, the steam engine, mechanics, and pneumatics.

Present-day teachers will probably be interested to learn that all chemicals used in the Day Schools were supplied by the teachers, the Lower School teachers being allowed five pounds per annum and the High School teachers ten pounds per annum for the purpose.

In 1848 an inventory was made of the instruments belonging to the Institute, the following being the complete list (*5*).

"A Catalogue of Instruments belonging to the Mechanics' Institution in repair. Powder House, Decomposing apps, Differential Thermometer, 3 Brass Conductors—Electrical Flask, Universal discharge and press—pair small plate glass handles—Solar Microscope—Electrometer—Glass tube and Stop cock—Filter cup for air—2 Brass plates—Glass Globe fountain—3 Cylindrical Cylinders—1 do for Guinea and feather apparatus—Copper flask—Best Bell—2 small open receivers—Bladder Glass—Barometer tube and Cup mounted—Egg stand—Wind gauge—Large glass Globe with brass cap—Apps for illustrating fly shuttle—pair bar Magnets and stand—10 Slides—2 Saccharometers—Floating Battery—Head of Hair—Flexible tube Camera Obscura—Syringe—Brass stand with table—Apps for Illus the Franklin theory of Leyden jar—Vibrating wire—2 Stands for Magnets—Magic picture—Centrifugal Jet—Hydrostatic Cylinder—Rotating do—Chemical Jet and brass tube—2 Hydrostatic apps—Inclined plane—Balance Lever—Whirling table with apps—Model of Governors for Steam Engine—Fountain—Model of Compound Lever—Wheel and axle—Rotating Magnet—Luminous plate—Riches Magnet and Rotator—Vibrating Magnet—Air pump plate—Brass pillar and foot—1 do do —Large Magic Lantern—Pith ball Electrometer—Pneumatic can—2 Chemical Thermometers—Set of Bells—long Chemical Thermometer—Brass Scale Thermometer—Sundry glass tubes with bulbs—Brass stand—Voltaic Magnet fountain jet—Chemical receiver—Barometer tube and Stop Cock—Sundry receivers—Glass Chair stool—Crofsley Rain gauge—apps for illus levers—Bent glass tube with scale—Disc pump without a handle—2 Galvanic Batteries—1 Conical Bell jar—1 U-tube (Syphon) broken—1 Volta's Eudometer—1 do do broken and useless—1 Gas jar with brass head and stop cock. Instruments wanting repairs—4 Glass Chemical receivers—Sustaining Bat-

tery—Cylinders for do—Cylinder Electrical Machine—Apps for illus principle of radiation—pair of Zinc Reflectors and Stands—7 rotating spiral—rotating fly Galvanic Battery—small do—Compound Magnet—Electrical Battery—Electro Magnetic globe—Model of force and lifting pump—Archimedean screws—Set of Mechanical pulleys—air pump no gauge—Rotating stands and Solids—Sectional Model valve—Set of 5 Bells—Hydrostatic Balance—Quadrant Electrometer Oersted's experiments Condensing syringe—2 of Guinea apps—1 do—2 pairs Hemisphere Sliding wire—Air pump Mill—Copper Globe for?—Apps for illustrating force of air—Gold leaf Electrometer—Coil Machine—Rotating Magnetic disc—ditto Star—Voltaire Magnet—Stand for dipping needle—Coil Machine—Gold leaf Electrometer—Differential Thermometer—Apps for decomposing Neutral salts—2 Quart jar—Quart Mullenser Battery—Model of Crane—Condensing Electrometer—Cylinder Electrical Machine—Cuthbertson discharge.

"The whole of the Apparatus very dirty and require a good Cleaning before they are fit for use.

"Copied from a list and letter headed 'List of Apparatus in Lower School, 1848 (*6*).' Henley's Electrometer—Gold Leaf Electrometer—Metallic discs—A box of specific gravity bulbs—Two Hydrometers—Two Chemical Thermometers—Two Magnets—Magnetic coil—Platinum Battery—Common Pot Battery out of repair—Lane's Electrometer—Rain Gauge—Hydrostatic Balance—Electrical Balance—Air pump—Condensing syringe—Guinea and Feather Apparatus—A set of windmills for demonstrating the resistance of the air—Beel Apparatus for proving air to be the medium of sound—Two Magdeburgh Hemispheres—Model of lifting and forcing pump—Two Hand and bladder glasses—Three artificial Fountains—one out of repair—Cylindrical Electrical machine and conductors—Dome and seven spirals—Glass flask—Universal discharger—A set of Four bells—Powder House—Aircannon—Pith ball Apparatus—Electric Balance—Barometer—Pith ball Electrometer—Electric Battery—Apparatus for showing that liquids will stand at the same level in two tubes when they communicate with each other—Apparatus for showing the effect of pressure on the spouting of fluids—Two models of Baker's mill out of repair—Archimede's Screw—Two pieces of Apparatus for showing the downward pressure of liquids, out of repair—Whirling table and Apparatus—Whirling stand and Apparatus—A model of a steam engine—Two simple levers—Two compound levers out of repair—Wheel and Axle Nos. 1 and 2—System of pulleys, out of repair—Inclined Plane—A model of the governor of steam engine—Two models of Cranes."

Another list, prepared in 1851, shows the apparatus belonging to the laboratory in the Lower School (*7*).

"List of Apparatus belonging to the Laboratory; Lower School. April 7th 1851. 1 still and worm—1 gasholder (complete)—1 oxygen gas bottle (Iron)—6 glass retorts—3 Florence flasks—1 Hydrogen gas bottle—1 Carbonic acid gas bottle—1 Sulphuretted Hydrogen jar, bottle and wash bottle with wooden stand—1 Liebig's condenser—2 Spherical glass receivers—1 Stoneware pneumatic trough—4 Gas jars—1 Deflagrating jar—2 Retort stands—1 Tripod and Shield—1 Measure glass—2 precipitating jars—2 large ditto—4 filters (glass)—2 large ditto (stoneware)—1 water bath for drying precipitate—5 test glasses—2 test tubes—3 Berlin porcelain crucibles—1 ditto ditto capsule—1 set stoneware evaporating dishes—2 Berlin porcelain ditto—3 common ware ditto—1 anvil—1 hammer—1 vice—3 files—set cork borers—1 pair charcoal tongs—1 pair crucible tongs—1 sand bath—1 Mortar and pestle—1 wooden stand—1 blowpipe—2 boxes charcoal supports—1 box test papers—1 box test metals. (Here follows a list of 95 chemical reagents.) A few pieces of glass tubing—1 washing bottle—1 spirit lamp—1 test tube rack.

"Specimens. Talc—Bromine—Iodine—Phosphoric acid—Citric acid—Cobalt—Bismuth—Nickel—Mercury—Potassium—Sodium."

A fair idea of the chemistry taught at this time can be gathered from the Report for 1852 (*8*) of which the following is an extract.

"The pupils begin what is called their Chemical course in the very lowest class, and continue it as long as they remain at school. In the lowest classes, it takes the humble name of 'Lessons on Objects.' Here a very great number of substances are brought under the eye of the pupils, and by the exercise of their senses and proper instruction, they learn to recognize them by something characteristic in each. The great value of these lessons will at once be perceived, inasmuch as they serve in no ordinary degree to awaken the observing faculties, and fix in the pupil's memory a great number of words and terms which he can spell accurately, and whose use and meaning he perfectly understands. When the pupils enter the sixth class, they have what is meant by chemical affinity explained to them, and are shewn a few of its most interesting exemplifications; as they advance, they are taught how to obtain oxygen, hydrogen, nitrogen, and chlorine, and, at the same time, have their wonder excited by a number of exhibitions of the properties of these gases. From this period they begin the study of the Atomic theory, the Chemical Nomenclature, and Chemical Notation: when sufficiently acquainted with these subjects, the metals are proceeded to: and thus, step by step, great care being always taken that the thing to be learned shall not overtask the ordinary powers of the class before the teacher, they gain a knowledge of all the most important and useful facts in chemistry. In the three senior classes all the pupils have much practice in experimenting with their own hands: this gives them an accurate knowledge of the chemical tests, and trains them to habits of expert manipulation and keen observation.

"It may be satisfactory to parents to know, that as the pupils proceed with their chemical course, the teacher loses no opportunity of pointing out the many useful applications of the science in the ordinary employments of men—in baking, brewing, cooking, tanning, dyeing, bleaching, cleansing, in purifying the air of dwellings, &c."

The table explains the time allotments in force in 1852 for the various subjects of the curriculum. It will be noticed that the curriculum was very much broader than was customary at that time and when it is remembered that Science teaching was first introduced into Rugby School in 1849 it is clear that the Liverpool Institute must be given the honour of having introduced the teaching of science into the curriculum.

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(4) Reports of Liverpool Mechanics' Institution, 1840–1854, (Vol. III, in the Library of the Liverpool Institute), March 10, 1841.

(5) Manuscript Inventory, dated 1848. (In the Liverpool Institute Library.)

(6) Manuscript List of Apparatus in Lower School, 1848. (In the Liverpool Institute Library.)

(7) Manuscript List of Apparatus belonging to the Laboratory; Lower School. April 7, 1851. (In the Liverpool Institute Library.)

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FIELD *and* LABORATORY MICROANALYSIS *by* MEANS *of a* PORTABLE DROP REACTION KIT

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MUCH of the published material on qualitative analysis is chiefly of academic interest, and procedures for field tests and practical applications in general are often confined to the blowpipe methods of the mineralogists, or to a few specific tests suitable only under certain conditions.

The interest of the authors in compact and portable equipment for general qualitative analysis has led to the development of a kit utilizing modern drop reactions

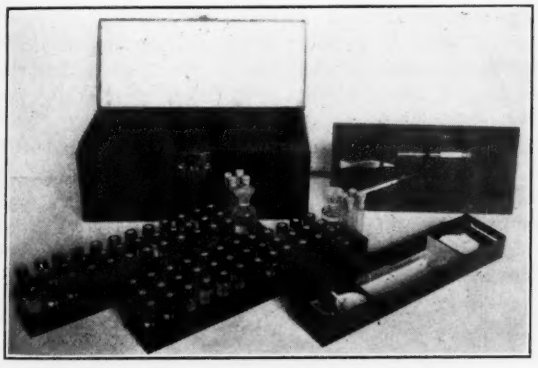

FIGURE 1

and microchemical technics. Since this kit has proved quite satisfactory in practice, and permits the application of adequate tests for rather a large number of constituents, a description is offered in the hope that it may be of general interest.

The entire kit is contained in a fishing tackle box, six by nine by fourteen inches, weighs nine pounds, comprises sixty-four reagents, and allows tests for thirty-eight constituents. Space for eight extra bottles is available in the kit as designed, allowing additional reagents to be added if desired.

APPARATUS

The apparatus consists of a thick concave slide (used as a mortar), small pestle, thin concave slide (placed on colored paper and used as spot plate), colored paper, cigarette lighter (used as burner), microscope slide, filter pipet (tapered capillaries with large end approximately 2 mm. in diameter), transfer pipets (capillaries approximately 1.0 mm. in diameter), platinum loop,

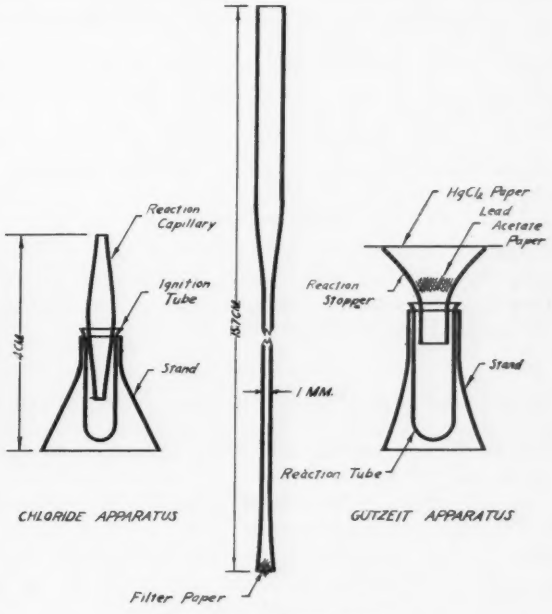

FIGURE 2.—FILTER PIPET

hand lens, centimeter rule, two watch glasses (micro preferred), cobalt glass, filter paper, razor blade, blowpipe for fusions, dissecting needle, chloride apparatus, Gutzeit apparatus.

REAGENTS

These are contained in 10-ml. vials equipped with screw caps carrying applicator rods. Small calendar numbers, cut out with a cork borer, and protected by similar disc of "scotch tape," are stuck on the caps for identification. The reagents chosen have been selected for their stability, availability, and definite reactions.

DETAILS OF TECHNIC

Preparation of sample: In the analysis of minerals

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or other substances not readily soluble in water or dilute hydrochloric acid, a sodium carbonate fusion is used, the details of which are as follows.

Sodium Carbonate Fusion.—Prepare a carbonate bead in the loop of a clean platinum wire. Touch the warm (or moistened) bead to some of the finely powdered unknown and fuse. When the material is homogeneous, introduce a little sodium peroxide into the melt. Place the bead in a casserole and leach with distilled water. Decant the supernatant liquid into a test-tube and label as "Aqueous Group." Add a drop or two of dilute hydrochloric acid to the residue in the casserole and, after solution is complete, rinse into a second test-tube with a little distilled water. Label this portion the "Acid Group."

Sodium Carbonate Separation.—Materials which are soluble in water or dilute HCl may be divided into two groups by adding a little sodium peroxide plus a little sodium carbonate to the solution and filtering by means of a filter pipet. The filter plug with the precipitate is then placed in the tube used for the acid group, and solution completed by addition of a few drops of dilute HCl plus a little water. The filtrate should be blown out into the tube used for the aqueous group.

The sodium carbonate separation and the fusion procedure both divide the elements into the two following groups.

Aqueous Group

Aluminum, antimony, arsenic, beryllium, boron, chloride, chromium, fluorine, iodine, molybdenum, phosphorus, potassium, selenium, silicon, sodium, sulfur, tin, tungsten, and vanadium.

Acid Group

Barium, bismuth, cadmium, calcium, cobalt, copper, gold, iron, lead, magnesium, manganese, mercury, nickel, silver, strontium, titanium, uranium, zinc, and zirconium.

Some elements such as aluminum, antimony, arsenic, beryllium, uranium, manganese, and zirconium may be found in both groups. Sodium, arsenic, mercury, and chloride should be run on the original sample.

Before starting the actual analysis the solutions of both groups should be made acid and boiled to decompose the remaining hydrogen peroxide. They should then be made neutral or faintly acid to litmus.

Filtering.—Filtration is carried out by placing a ball of moist filter paper in the bell of a filter pipet and sucking the liquid up into the body of the pipet. The filter paper is then removed and the filtrate blown into the receiving vessel. If the filtrate is to be tested on filter paper a simple procedure is to allow the solution and precipitate to be drawn into a capillary tube, the end of the capillary placed firmly against a piece of filter paper held on a smooth surface, and the liquid allowed to diffuse out into the paper. The precipitate, which will remain at the center of the spot, will not interfere with subsequent tests.

General Hints.—In preparing the material for solution it is well to remember that HCl gives insoluble precipitates with Ag^+, Hg^+, Pb^{++}, Tl^+, Cu^+, Au^+, Sb^{+++++}, and Bi^{+++}, alkaline silicates are broken down to SiO_2, and insoluble oxides of arsenic, tellurium, tungsten, titanium, and molybdenum are formed. Any insoluble material should be filtered off, fused, and taken into solution by whatever means might apply.

Observation of the preliminary treatment may give a good idea of the composition of unknowns. For example, the formation of a precipitate upon addition of HCl indicates that one of the substances mentioned above is present. A pink or yellow color upon addition of HCl indicates the presence of titanium or vanadium (resulting from the reaction of these elements with hydrogen peroxide which is formed when sodium peroxide is treated with acid).

The spot plate (a slide of the type used for hanging drop technic in bacterial work) used in this kit lends itself readily to various phases of the technic. It may be held over colored backgrounds as an aid in observing precipitates, and will also stand gentle heat in cases where the reactions must be hastened by heating. Care of the apparatus consists essentially of using only fresh capillary tubes each time, and washing and drying the casseroles, spot plates, and so forth, after each test.

As a general rule in applying the tests, it is well to keep in mind that small drops used consistently will give as good results as large drops. The strength of the solution of the unknown need never be over 0.5 per cent.

Stannous chloride, bromine water, concentrated HCl, H_2SO_4, and NaOH attack the vial caps and therefore should not be left in the vials for more than a few days before being replaced.

In the description of the tests which follow, the elements are placed in alphabetical order in their respective groups. This is to facilitate locating specific procedures when testing for random elements.

REAGENTS

(1) Acetic acid (2 *N*).
(2) Alizarin: To a saturated solution of alizarin in alcohol add HCl until yellow. Dilute with an equal amount of alcohol and filter.
(3) Alizarin S. (One per cent.)
(4) Ammonia (concentrated).
(5) Ammonium carbonate (5 *N*).
(6) Ammonium chloride (saturated).
(7) Ammonium mercury thiocyanate: 9 g. $(NH_4)CNS$ and 8 g. $HgCl_2$ dissolved in 100 ml. of water.
(8) Ammonium molybdate: Add 35 ml. of HNO_3 (sp. gr. 1.2) to 100 ml. of a five per cent. solution of $(NH_4)_2MoO_4$.
(9) Ammonium persulfate (solid).
(10) Ammonium phosphate ($(NH_4)_2HPO_4$) (5 *N*).
(11) Ammonium sulfide (concentrated).
(12) Aniline: Saturated solution of aniline hydrochloride in concentrated HCl.
(13) Barium chloride (*N*).
(14) Benzidine: Dissolve 0.05 g. benzidine in 10 ml. glacial acetic acid. Dilute to 100 ml. with water.
(15) Bromine water.
(16) Codeine sulfate (three per cent.).
(17) Copper sulfate (0.02 per cent.).
(18) Dihydroxytartaric osazone (solid).

(19) Dimethyl-amino-benzal rhodanine: 0.03 per cent. in acetone.
(20) Dimethylglyoxime: One per cent. in alcohol.
(21) Diphenylcarbazide: (Make up fresh.) One per cent. in alcohol.
(22) Diphenylcarbazide thiocyanate: (Make up fresh.) To a saturated alcohol solution of diphenyl carbazide, add potassium thiocyanate crystals to saturation.
(23) Diphenyl thiocarbazone (dithizon): 0.002 per cent. in carbon tetrachloride. This reagent attacks ordinary glass and so should be kept in pyrex.
(24) Hydrochloric acid (concentrated).
(25) Hydrochloric acid (0.1 *N*).
(26) Hydrogen peroxide (twenty per cent.).
(27) Magnesium powder.
(28) Mercuric chloride (saturated).
(29) Mercuric nitrate: ten per cent. mercuric nitrate in one per cent. nitric acid.
(30) Nitric acid (*N*).
(31) α-Nitroso-β-naphthol: Dissolve 2 g. α-nitroso-β-naphthol in 100 ml. glacial acetic acid and dilute with 100 ml. water.
(32) Oxalic acid (2 *N*).
(33) Phosphomolybdic acid (five per cent.).
(34) Phosphoric acid (concentrated).
(35) Potassium chromate (*N*).
(36) Potassium chromate: one per cent. in normal acetic acid.
(37) Potassium cyanide (5 *N*).
(38) Potassium dichromate (solid).
(39) Potassium ferrocyanide (2 *N*).
(40) Potassium iodide (*N*).
(41) Potassium nitrite (*N*).
(42) Potassium thiocyanate (2 *N*).
(43) Potassium thiocyanate (solid).
(44) Quinalizarin (saturated in alcohol).
(45) Silver nitrate (solid).
(46) Sodium acetate (saturated).
(47) Sodium carbonate (anhydrous).
(48) Sodium cobaltinitrite (solid).
(49) Sodium hydroxide (5 *N*).
(50) Sodium hydroxide (*N*/10).
(51) Sodium peroxide (solid).
(52) Sodium phosphate (Na_2HPO_4) (2 *N*).
(53) Sodium rhodizonate (make up fresh) (five per cent.).
(54) Sodium thiosulfate (*N*).
(55) Stannous chloride: Normal in concentrated HCl.
(56) Starch (solid).
(57) Sulfuric acid (concentrated).
(58) Thiourea (ten per cent.).
(59) Titan Yellow (0.1 per cent.).
(60) Turmeric: Extract 20 g. turmeric with 50 ml. alcohol, filter, and dilute to 100 ml. with water.
(61) Zinc (arsenic free).
(62) Zinc sulfate (2 *N*).
(63) Zinc uranyl acetate.
(64) Zirconium-alizarin lake: Add equal volumes of 0.17 per cent. alizarin S. to 0.87 per cent. zirconium nitrate and dilute with five volumes of water.

ANALYTICAL PROCEDURES

APPARATUS	PROCEDURE WITH EXPLANATORY NOTES	COLOR
	AQUEOUS GROUP	
	Aluminum	
Spot plate	1 drop of solution, 1 drop of NaOH (*N*/10), 1 drop of alizarin S., 2 drops acetic acid. Note: Most interfering substances are precipitated during the preparation of the sample. Some such as Mo, Cr, and V, which are not, may be removed by boiling with 1 drop of $BaCl_2$: the excess Ba must then be removed with NaOH, evaporating to dryness, taking up in 2 drops of H_2O and filtering. LI = 0.6 microgram LC = 1:77,000	Pink
	Antimony	
Filter paper	(A) Watch glass: 1 drop of solution, 1 drop of ammonium sulfide, remove excess liquid, 1 drop of HCl (conc.). (B) Filter paper: 1 drop of phosphomolybdic acid, 1 drop of solution (A), hold in steam. Note: The above treatment of the sulfide precipitate gives the antimony as $SbCl_3$ and any tin as $SnCl_4$. Under such conditions, the test is specific for antimony. If tin is known to be absent, proceed from (B). The color formation is slow, but is hastened by the steaming. LI = 0.2 microgram LC = 1:250,000	Blue
	Arsenic	
Gutzeit apparatus	Place a few grains zinc, 1 ml. HCl (*N*/10), 4 drops of $SnCl_2$ in the apparatus. Add a few drops of test solution and close the apparatus with assembled stopper. Note: This test is specific. The stopper is assembled by placing PbAc paper in the body of the tube (to remove any H_2S) and placing $HgCl_2$ paper over the top of the tube. Instead of using lead acetate paper, it is often advantageous to place a loose plug of cotton saturated with Cu_2Cl_2 in the body of the tube—the Cu_2Cl_2 will remove PH_3 and SbH_3 as well as H_2S. LI = 1 microgram LC = 1:40,000	Yellow-brown
	Beryllium	
Casserole	1 drop of solution, 1 drop of HCl (*N*/10), evaporate to dryness and bake to expel NH_4^+ salts. Dissolve in 1 drop of NaOH (*N*/10), add 2 drops quinalizarin. Notes: Run blank. NH_4^+ interference is prevented by its decomposition. Interference from iron and magnesium does not occur in this procedure because of their separation during the preparation of the sample. LI = 0.15 microgram LC = 1:353,000	Blue
	Boron	
Casserole	1 drop of turmeric, 1 drop of solution, 1 drop of HCl (*N*/10), evaporate to dryness, 1 drop of NaOH (5 *N*). Notes: Some other compounds give a stain (reddish brown) with this reagent, but their color is not changed	Green

	to green by the NaOH treatment. Oxidizing agents such as nitrites, chromates, and so forth, must be decomposed before applying this test. LI = 0.02 microgram LC = 1:2,500,000	
	Chloride	
Special apparatus	A few grains of the solid substance are mixed with powdered potassium dichromate and placed in the ignition tube of the chloride apparatus. A drop of H_2SO_4 (conc.) is added, and the charged reaction capillary put in place. Heating the ignition tube will color the reagent in the capillary purple. The reaction capillary is charged by touching its tip to a drop of freshly prepared diphenylcarbazide. Note: This test may be made in the presence of iodine and bromine if a little phenol is added to the ignition tube. Gives no test with insoluble chlorides (AgCl). LI = 1.5 micrograms LC = 1:33,000	Purple
	Chromium	
Spot plate	One drop of solution, acidify (H_2SO_4), 1 drop of diphenylcarbazide. Note: Molybdenum and vanadium interference may be inhibited with oxalic acid. LI = 0.5 microgram LC = 1:100,000	Violet
	Fluoride	
Spot plate	One drop of solution, 1 drop of HCl (conc.), 1 drop of H_2SO_4 (conc.), 1 drop of zirconium-alizarin solution. Allow to stand five minutes. Run blank. Notes: Phosphates, arsenates and oxalates interfere. Interference from oxalates may be prevented by roasting the sample prior to testing. LI = 2 micrograms LC = 1:250,000	Fades from pink to yellow
	Iodine	
Spot plate	One drop of solution, 1 drop of HCl ($N/10$), 1 drop of fresh starch paste, 1 drop of KNO_2. Notes: Specific. LI = 2.5 micrograms LC = 1:20,000	Blue
	Molybdenum	
Filter paper	One drop of HCl (conc.), 1 drop of solution (on acid spot), 1 drop KCNS, 1 drop of $SnCl_2$. Note: Both molybdenum and tungsten react with KCNS in the presence of $SnCl_2$ and HCl. The molybdenum gives a red color soluble in the HCl (therefore the red is at the *edge* of the drop); the tungsten reacts to give a blue, insoluble ppt. (remains in the center of the drop). LI = 0.1 microgram LC = 1:25,000	Red (edge of spot)
	Phosphorus	
Casserole	Two drops of ammonium molybdate, 1 drop of solution, 1 drop of benzidine, 3–6 drops of Na acetate. Notes: Soluble silicates and phosphates both react with ammonium molybdate in nitric acid solution to form complex molybdates. When these complex molybdates are treated with benzidine, they are reduced to molybdenum blue, and simultaneously the benzidine is oxidized to a blue quinoid compound. Phosphates react to form the molybdates in the cold, while the silicates require gentle heating before they undergo the reaction. If silicates are present, they may be removed by converting to insoluble silica by twice evaporating the test portion to dryness in the presence of HCl. The residue may then be leached with dilute HNO_3 and the test applied. LI = 0.05 microgram LC = 1:1,000,000	Blue
	Potassium	
Spot plate	One drop of solution, 1 drop of acetic acid, a few grains of sodium cobaltinitrite. Heat gently. Notes: Thallium and lithium yield precipitates which cannot be distinguished from the potassium test; therefore, in the presence of these elements, the cobaltinitrite test cannot be used. The next best test is the violet flame shown by potassium compounds when viewed through cobalt glass. LI = 4 micrograms LC = 1:12,500	Yellow ppt.
	Selenium	
Casserole	One drop of solution, 5 drops of sulfuric acid (conc.), digest until colorless (cover casserole to prevent excessive evaporation), cool, add 1 drop of codeine sulfate. Notes: Vanadium is the only interfering substance. LI = 0.08 microgram LC = 1:8,000,000	Blue
	Silicon	
Casserole	Two drops of ammonium molybdate, 1 drop of solution, warm, cool, 2 drops of oxalic acid, 1 drop of benzidine, 3–8 drops of sodium acetate. Notes: See notes on phosphorus. To detect silicon when phosphate is present add 1 drop of solution to two drops of reagent, warm, filter off the precipitate of ammonium phosphomolybdate, cool the filtrate and proceed as before. LI = 1 microgram SiO_2 LC = 1:50,000 In presence of phosphate LI = 6 micrograms SiO_2 (in presence of up to 250 parts P_2O_5) LC = 1:8300	Blue

Sodium

Spot plate	(A) Watch glass: 2 drops of solution, 1 drop of ammonium sulfide, 1 drop of $(NH_4)_2CO_3$, filter. (B) Spot plate: Place filtrate from "A" on a spot plate, neutralize with acetic acid; 6–8 drops of zinc uranyl acetate. Notes: The treatment with ammonium sulfide removes all interfering elements, thus making the test specific. LI = 12.5 micrograms LC = 1:4000	Yellow

Sulfur

Casserole	One drop of solution, 1 drop of Hg $(NO_3)_2$, evaporate nearly to dryness, 2 drops of water. Notes: The method of fusing substances in the presence of sodium peroxide in preparing them for solution oxidizes any sulfur compounds to sulfate, which, when evaporated with the reagent and treated with a drop of water, forms a yellow basic mercuric sulfate. The test is specific. LI = 1.2 micrograms LC = Solution is evaporated to near-dryness.	Yellow

Tin

Filter paper	(A) Watch glass: 1 drop of solution, 1 drop of ammonium sulfide, absorb excess liquid, 1 drop of HCl (conc.), a few grains powdered magnesium. (B) 1 drop of solution from "A," 1 drop of phosphomolybdic acid. Notes: See notes under antimony. When the sulfide precipitate is dissolved in acid and reduced, any tin present reacts with phosphomolybdic acid to give a blue color. The test is specific even in the presence of antimony. LI = 0.03 microgram LC = 1:1,670,000	Blue

Tungsten

Filter paper	One drop of HCl (conc.), 1 drop of solution in center of acid spot, 1 drop of KCNS, 1 drop of $SnCl_2$. Notes: See notes under molybdenum. LI = 4 micrograms LC = 1:12,500	Blue

Vanadium

Filter paper	One drop of aniline, 1 drop of HNO_3, 1 drop of solution. Notes: Chromates give similar stains, but may be reduced to chromium chloride, which does not react, by boiling with concentrated HCl. LI = 4 micrograms LC = 1:9000	Green

ACID GROUP

Barium

Filter paper	One drop of solution, 1 drop of fresh sodium rhodizonate, 1 drop of HCl ($N/10$). Notes: Ba, Sr, and Pb all react with this reagent, but treatment of the stain with dilute HCl serves as a means of differentiation—with the HCl, the Sr stain disappears at once, the Ba stain fades more slowly, and the Pb stain turns purplish. Ba can thus be detected in the presence of Sr and Pb. LI = 0.25 microgram LC = 1:200,000	Brown

Bismuth

Spot plate	One drop of solution, 1 drop of thiourea, 1 drop of HNO_3. Notes: Specific in absence of members of the aqueous group. LI = 0.5 microgram LC = 1:75,000	Yellow

Cadmium

Spot plate	One drop of diphenylcarbazide thiocyanate, 1 drop of solution, 1 drop of NH_4OH. Note: Co gives the same reaction; therefore in its presence the test is inconclusive. Interference from other elements is inhibited by the presence of NH_4OH. Since the reagent is colored, a blank should be run. LI = 4 micrograms LC = 1:12,500	Violet

Calcium

Spot plate (black)	(A) Watch glass: 1 drop of solution, 1 drop of ammonium sulfide, warm, filter. (B) Spot plate: Blow out the filtrate from "A" on a spot plate, add a few grains dihydroxytartaric osazone. Notes: Interfering substances are removed by the $(NH_4)_2S$ treatment. The reaction is slow, and fifteen minutes may be needed before a noticeable precipitate is obtained with small amounts of Ca. LI = 0.01 microgram LC = 1:5,000,000	White precipitate

Cobalt

Spot plate	(A) Watch glass: 1 drop of solution, 1 drop of NH_4Cl, 2 drops of NH_4OH, 2 drops of H_2O. Filter. (B) Watch glass: Filtrate from "A," 2 drops of phosphoric acid, 1 drop of potassium iodide, 2 drops of sodium thiosulfate. (C) Spot plate: Filtrate from "B," 1 drop of α-nitroso-β-naphthol. Notes: If desired, greater sensitivity may be obtained by use of β-nitroso-α-naphthol. Most interfering substances are removed by the ammonium hydroxide precipitation. The second precipitation with potassium iodide removes any interfering	Brown

	copper as Cu_2I_2; free iodine, also produced in the reaction, is destroyed by the $Na_2S_2O_3$. Nickel also gives a brown color with this reagent, but it may be faded by a drop of dilute HCl. If iron, zirconium, vanadium, copper and nickel are known to be absent proceed from "C." LI = 0.1 microgram LC = 1:1,000,000	
	Copper	
Casserole	One drop of solution, 1 drop of $(NH_4)_2HPO_4$, acidify (conc. H_2SO_4), 1 drop of $ZnSO_4$, 1 drop of ammonium mercuric thiocyanate, warm. Notes: Iron interference is inhibited by the phosphate. Cobalt and nickel interfere. LI = 0.1 microgram LC = 1:500,000	Violet
	Gold	
Filter paper	One drop of solution, 1 drop of $SnCl_2$, 1 drop of KCNS, boil in water. Notes: Mercury and selenium interfere, and in their presence the test is indeterminate. Molybdenum gives a stain similar to that of gold, but the color fades upon addition of potassium thiocyanate and boiling. LI = 3 micrograms LC = 1:10,000	Purple
	Iron	
Spot plate	One drop of solution, 1 drop of KCNS, 1 drop of HCl (N/10). Note: If arsenates, oxalates, tartrates, and so forth, are present they must be destroyed by roasting or by the fusion procedure. Molybdenum, fluoride, and phosphate do not interfere as they appear in the aqueous group. LI = 0.25 microgram LC = 1:200,000	Red
	Lead	
Spot plate	One drop of solution, 3 drops of KCN, 1 drop of NH_4Cl, 1 drop of dithizon. Notes: Run blank, as the potassium cyanide imparts some color to the reagent. Dithizon gives a specific test for lead in the presence of potassium cyanide and ammonium chloride. The reagent should be a deep green color, and should be prepared fresh five or six times a year. It is well to keep a stock solution in a pyrex bottle and fill the vial only before taking the kit into the field. LI = 0.1 microgram LC = 1:1,000,000	Pink
	Magnesium	
Spot plate	(A) Watch glass: 1 drop of solution, 1 drop of ammonium sulfide, warm, filter. (B) Spot plate: Filtrate from "A," 1 drop of titan yellow, 1 drop of NaOH (N/10). Notes: All interfering substances are removed by the ammonium sulfide. The sulfide separation may be omitted if iron, cobalt, cadmium, or nickel alone are present by adding a drop of potassium cyanide prior to the addition of the reagent and alkali. LI = 1.5 micrograms LC = 1:3300	Pink
	Manganese	
Casserole	One drop of solution, 1–4 drops of $AgNO_3$, 1 drop of H_3PO_4, a few grains ammonium persulfate, warm. Notes: Chloride, bromides, and so forth, do not interfere if sufficient silver nitrate is added to insure an excess over that required to precipitate the halogen. Under these conditions the reaction is specific. LI = 0.1 microgram LC = 1:500,000	Violet
	Mercury	
Filter paper	Watch glass: 1 drop of solution, 1 drop of hydrochloric acid (1 N), 4 drops of Na_2HPO_4, filter on filter paper, 1 drop of dimethyl-amino-benzal rhodamine on edge of spot. Notes: Any interference from silver or copper is prevented by their precipitation with the hydrochloric acid and sodium phosphate. Because of the color of the reagent, it is well to run a blank. LI = 1 microgram LC = 1:50,000	Pink
	Nickel	
Filter paper	Watch glass: 1 drop of solution, 1 drop of hydrogen peroxide, 1 drop of ammonium carbonate, 1 drop of ammonia. Filter on paper, 1 drop of dimethylglyoxime on edge of spot, warm. Notes: Any interference due to iron, cobalt, or manganese is prevented by their removal with ammonium carbonate. LI = 1 microgram LC = 1:300,000	Pink
	Silver	
Spot plate	A. Watch glass: 1 drop of solution, 1 drop of $(NH_4)_2CO_3$, filter. B. Spot plate: filtrate from "A," 1 drop of K_2CrO_4, 1 drop of acetic acid. Notes: Any interfering substances are precipitated by the $(NH_4)_2CO_3$ so that the test is specific. If in a laboratory, observe the test under a yellow light as greater sensitivity may be obtained. LI = 0.8 microgram LC = 1:40,000	Red
	Strontium	
Filter paper	One drop of solution, 1 drop of K_2CrO_4, 1 drop of sodium rhodizonate on edge of spot. Notes: See notes under barium. Interference from lead and barium is	Brown

prevented by their precipitation as the chromate.

LI = 3.9 micrograms (in presence of barium or lead) or 0.45 microgram (strontium alone)

LC = 1:12,800

Titanium

Spot plate	One drop of solution, 1 drop of H_3PO_4, 1 drop of H_2O_2.	Yellow

Notes: Molybdenum, vanadium, and chromium appear in the aqueous group and so do not interfere. Iron interference is prevented by the phosphoric acid.

LI = 2 micrograms
LC = 1:2500

Uranium

Filter paper	Watch glass: 1 drop of solution, four drops of $Na_2S_2O_3$. Filter on filter paper, one drop of potassium ferrocyanide on edge of spot.	Brown

Note: The sodium thiosulfate reduces any iron and copper and precipitates any titanium as TiO_2. There are no other substances which interfere.

LI = 4 micrograms
LC = 1:12,500

Zinc

Casserole	One drop of solution, 1 drop of $(NH_4)_2HPO_4$, 2 drops of H_2SO_4, 1 drop of $CuSO_4$, 1 drop of ammonium mercuric thiocyanate, warm.	Violet

Notes: See notes for copper. Large amounts of copper interfere and should be removed by precipitation with KI. The free iodine set free should be destroyed by adding a drop of $Na_2S_2O_3$.

LI = 0.2 microgram
LC = 1:250,000

Zirconium

Spot plate	One drop of solution, 1 drop of HCl, 1 drop of alizarin, heat gently.	Brown to pink

Notes: Specific under test conditions.

LI = 0.5 microgram
LC = 1:100,000

DISCUSSION

The convenience and compactness of the equipment described, combined with its wide applicability, will suggest numerous uses to its possessor. Each individual will undoubtedly wish to introduce variations in content and procedure to suit his particular needs.

While the tests used are given in the majority of cases either by Watson or by Feigl, they have been modified to conform with the two group separations obtained in the preparation of the sample for analysis. This preliminary separation removes many interfering substances and therefore must be made before applying the above tests.

If additional confirmation of the presence of a given constituent is desired, it will be found in many cases that the reagents and apparatus included may be used, under slightly modified conditions, for detection of substances other than those for which they were included. Thus, diphenylthiocarbazone may be used to confirm Cu, Zn, Hg, Au, and Ag; the flame test for Sr, Na, and K; H_2O_2 for V; Pb may be confirmed by either the sulfide or chromate tests; HCl and Zn may be used for W; quinalizarin will serve for Mg, and the SiF_4 reaction for fluorine.

ACKNOWLEDGMENT

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THE CHANGE IN THE NAME OF *THE AMERICAN PHYSICS TEACHER*

American Journal of Physics is the new title of the bimonthly publication known since its inception in 1933 as *The American Physics Teacher*, according to an action taken recently by the American Association of Physics Teachers concerning its official journal. Remaining under the editorship of Professor Duane Roller, of Hunter College, and under the publication management of the American Institute of Physics, the journal will continue to stress the educational, historical, socio-economic and philosophic aspects of physics, and the instruction of students who take physics as part of a liberal education as well as those who specialize in the science.

On DILUTE SOLUTIONS *of* ELECTROLYTES

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THE Debye-Hückel-Onsager theory of strong electrolytes (*1*, *9*), with its concept of the ion atmosphere, being a net result of the Coulomb attraction forces and the thermal vibrations, has given us an exact quantitative picture of the limiting law of reversible as well as of different irreversible properties of ionic solutions.

The problem of the specific, individual deviations from this law at finite concentrations (say, at 10^{-3} to about 5×10^{-2} molar in water), however, has not reached its final solution. In the case of relatively small inorganic univalent ions, the individualities may be accounted for by means of their different degrees of solvation, *e. g.*, different ionic diameters (*11*), which may be taken into consideration when computing the electrostatic forces according to Debye and Hückel. In many other cases, however, this correction does not suffice.

According to recent work by Lange (*5*), McBain (*8*), Kortüm (*4*), and others,[2] one is forced to take into account also the van der Waals forces, especially the additive London dispersion forces (*7*). These have been shown to be of considerable importance for the behavior of certain ionic solutions, since they sometimes are as strong as to cause association even between ions of equal charge, in spite of the electrostatic repulsion.

Let us consider the familiar conductance and osmotic properties. The experimental material for uni-univalent strong electrolytes at 0°C. may, in the concentration range here studied, be represented by the following equations

$$1 - f_\sigma = j = 0.374 \times c^{\frac{1}{2}} + B_\sigma \times c \qquad (1)$$

$$1 - f_\mu = (0.219 + 29.5/\Lambda_0) \times c^{\frac{1}{2}} + B_\mu \times c \qquad (2)$$

where $f_\sigma = \vartheta/(\nu \times 1.859 \times m)$ and $f_\mu = \Lambda/\Lambda_0$ are the well-known osmotic and conductivity coefficients. The first term on the right side gives in either equation the limiting law, and the second term represents the individual properties of the electrolyte.

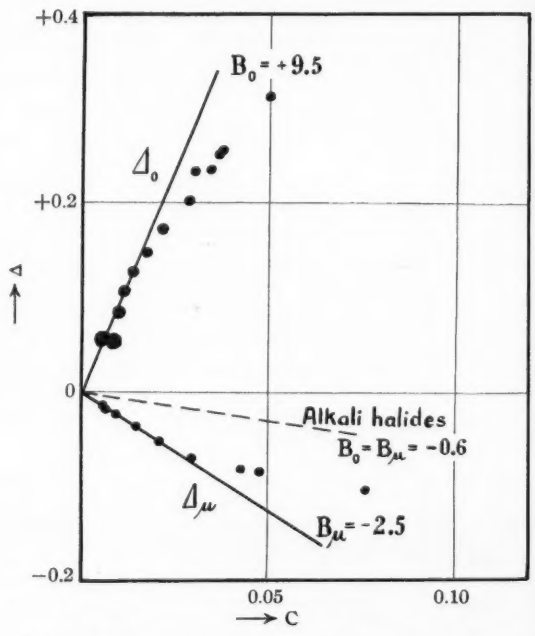
The alkali halides have coefficients $B_\sigma = B_\mu = -0.6 \pm 0.2$, as has been pointed out by Lange (*5*). These, and other electrolytes having about the same coefficients, are regarded as ideal ones in the sense that the electrostatic effects are so dominant as to submerge the specific, individual properties at these concentrations.

[1] Research Chemist.

[2] Compare for instance KIELLAND, J. CHEM. EDUC., **14**, 412 (1937).

Lange also for the first time tried to estimate the London dispersion forces in ionic solutions, and was able to show that the order of magnitude was such as to account for the individualities observed in the osmotic behavior of the alkyl ammonium halides studied by himself.

From the combination of osmotic and conductance studies, Lange and Herre (*6*) recently evaluated the observed van der Waals effects in terms of formal association of ions of equal as well as of opposite sign. The results were particularly interesting, as it could be definitely shown that in some cases the van der Waals forces between ions of like sign were much stronger than between those of opposite sign (examples, sodium picrate and dinitrophenolate).



SODIUM DIPICRYLAMINATE IN WATER AT 0°C. DETERMINATION OF B-CONSTANTS FROM OSMOTIC AND CONDUCTOMETRIC MEASUREMENTS

We have studied a strong electrolyte, sodium dipicrylaminate, which was found to have a very high and positive coefficient B_σ (+9.5), together with a coeffi-

cient B_μ (−2.5) still more negative than any electrolyte studied by Lange. Accordingly, very strong van der Waals forces must occur in this case, and particularly between the two univalent anions, which probably must possess quite large polarizabilities.

The B-coefficients were calculated from our measurements (*3*) by the procedure of Lange and Herre (*6*), by plotting (Figure 1) against c the functions

$$\Delta_\sigma = 1 - f_\sigma - A_\sigma \times c^{\frac{1}{2}} \quad (3)$$

$$\Delta_\mu = 1 - f_\mu - A_\mu \times c^{\frac{1}{2}} \quad (4)$$

The formal degrees of association were also computed as done by these authors, taking into consideration

TABLE 1

ASSOCIATION OF STRONG ELECTROLYTES AT 10^{-2} MOLAR SOLUTION IN WATER AT 0°, DUE TO VAN DER WAALS FORCES

Electrolyte	B_σ	B_μ	Per cent. association of ions with Equal sign	Per cent. association of ions with Opposite sign	The non-ideal free energy decrease, cal. per mole Electrostatic effects[3]	The non-ideal free energy decrease, cal. per mole van der Waals effects[4]
LiCl	−0.65	−0.74	0.2	0.0	53	0
LiI	−0.85	−0.92	0.0	(−0.2)	53	(−1)
KF	−0.54	−0.61	0.0	(−0.1)	55	0
KCl	−0.64	−0.46	(−0.3)	0.0	55	(−1)
KI	−0.64	−0.76	0.1	(−0.2)	55	(−1)
CsCl	−0.35	−0.49	0.4	0.0	55	1
CsI	−0.59	−0.53	0.0	0.0	55	0
HIO_3	+1.3	+2.6	1.7	3.6	51	24
KIO_3	+0.03	−0.42	1.2	0.3	55	6
$KClO_3$	−0.15	−0.35	0.9	0.3	55	4
$KClO_4$	+0.08	+0.03	1.1	0.7	55	6
H-Picrate	+2.18	+0.81	8.8	1.9	53	32
Na-Picrate	+1.15	−1.67	7.6	0.5	53	21
Na-Dinitrophen.	+0.79	−1.49	6.0	0.3	53	17
Na-Dipicr. amin.	+9.5	−2.5	35.2	3.7	53	112
$N(CH_3)_4Cl$	−0.4	+0.3	(−0.2)	0.7	56	1
$N(CH_3)_4I$	+0.1	+0.8	0.4	1.4	57	6
$N(C_3H_8)_4Cl$	−0.3	+0.1	0.2	0.7	55	3
$N(C_3H_8)_4I$	+0.2	+0.6	1.1	1.4	56	9
$N(C_3H_7)_4Cl$	−0.3	+0.8	(−0.3)	1.5	53	5
$N(C_3H_7)_4I$	+0.6	+1.6	1.2	2.6	54	15
$N(C_4H_9)_4Cl$	−0.7	+0.4	(−0.6)	1.2	54	2
$N(C_4H_9)_4I$	+1.4	+2.5	2.7	4.0	54	25

[3] Equal to $[605 \times m^{\frac{1}{2}} + 1080 \times m \times B^0{}_{(el.static)}]$
[4] Equal to $[1080 \times m \times (B_\sigma - B^0{}_{(el.static)})]$

Lange's empirical equation $B_\sigma = B_\mu$ for the electrostatic forces. Instead of Lange's $B_{\sigma(el.static)} = -0.6 \pm 0.2$, we have used values from −0.5 to −0.9 in order to take into consideration the small differences caused by the probable ionic diameter (*11*) of the ions in question. The formulas for the degrees of association finally become, for ions with like sign (double ions)

$$\delta = [4(B_\sigma + V_i^0/1000 - B_{el.static}) - 2(B_\mu - B^0{}_{el.static})] \times c/(1 + 2\varphi t) \quad (5)$$

and opposite sign (ionic pairs)

$$\gamma = (B_\mu - B^0{}_{el.static}) \times c + \delta\varphi t \quad (6)$$

The limiting conductivity of dipicrylaminate anion was determined by us to $\Lambda_0 = 12.8$ at 0°C., giving the transference number $t^- = 0.332$ of the sodium salt. The function φ[5] at 0°C. was computed equal to 0.46 at 10^{-2} molar, from Lange's equation

$$\varphi = 0.6 - [0.54 + 5.9/\Lambda_0 + 0.64 \times t]/[1/c^{\frac{1}{2}} - (0.22 + 14.7/\Lambda_0)] \quad (7)$$

The results obtained for sodium dipicrylaminate as well as for electrolytes measured by Lange, are given in Table 1, columns 4 and 5.

In order to give a more complete picture of the magnitudes of the two principal sources of interionic forces, we have also calculated[6] the non-ideal free energy due to electrostatic forces as well as to the individual van der Waals forces, and the results are seen from Table 1, columns 6 and 7.

Strong van der Waals forces (*molecule-molecule* effect[7]) are characterized by the empirical fact that the relative heat content change in this case has the same sign as the free energy change, and is equal to it in magnitude or larger, corresponding to the old rule that all dissociations increase with increasing temperature. The electrostatic forces (*charge-charge* effect), however, have free energy and heat content changes with opposite signs in the limiting law, while the heat content change of the *charge-molecule* effect is almost zero.

These facts furnish a convenient and rapid method of detecting such pronounced van der Waals effects which renders the pure electrostatic theory of electrolytes insufficient. Thus, in the case of dipicrylaminate, our measurements (*3*) indicate at 0.05 molar about −0.5 kcal. per mole, for $\bar{F}_2 - \bar{F}_2^0$ as well as for $\bar{H}_2 - \bar{H}_2^0$; hence, very strong forces of the molecule-molecule type must be present.

It is important to have in mind that some of the common strong electrolytes do show large van der Waals forces between ions of equal sign even in dilute solution. This fact must for example influence the application of semi-empirical and theoretical equations to the thermodynamic properties of mixtures of electrolytes, since they are (*2*) commonly based upon Brønsted's principle of specific ion interaction, which takes into account forces between ions with opposite sign only.

Much remains, however, to be done regarding the quantitative and theoretical treatment of dilute solutions of electrolytes. Thus we know at present very little about the distribution of the van der Waals forces within the three following groups: Keesom's orientation effect, Debye's induction effect, and London's dispersion effect.

[5] $1 + \varphi$ = the ratio between the equivalent conductivity of the double anion and that of the single ion.

[6] Putting $m = c$ at small concentrations, we get for thermodynamic reasons the following equation for the mean stoichiometric activity coefficient of the solute:

$$-2.303 \times \log_{10} f_\pm = 3 \times 0.374 \times m^{\frac{1}{2}} + 2 \times B_\sigma \times m$$

which facilitates the energy computations (it is seen that for $B_\sigma = 0$, we obtain the well-known limiting expression $-\ln f_\pm = 3 \times j$).

[7] See pp. 22–3 in the excellent review of Scatchard (*10*).

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HIGH-SCHOOL NOTES

ELBERT C. WEAVER[1]

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SUGGESTION

IN ORDER to visualize the idea of valence I supply pupils with short lengths of copper wire and modeling clay of different colors. Using these materials, the pupils are required to construct simple models of compounds. Wads of clay represent atoms of elements and the wires the valence bonds. Each element has a separate color assigned. Within a short time pupils make satisfactory models of ternary compounds.—DOROTHY G. HIMES, Polytechnic High School, Long Beach, California.

INQUIRIES

Why are the most active elements of the alkaline metal group at the *foot* of Group I?—DOROTHY G. HIMES.

Why can safety matches be ignited by scratching them on window glass?—DOROTHY G. HIMES.

In the electrolysis of alumina in fused cryolite by the Hall process is elementary fluorine first liberated? If so, does this in turn replace oxygen?—E. C. WEAVER.

Most elementary chemistry textbooks give the following order for electrochemical replacement: K^+.., H^+.., Ag^+. Later on the following equation is given without explanation for the apparent contradiction.

$$H_2S + 2Ag \longrightarrow Ag_2S + H_2$$

How is this inconsistency best explained to high-school pupils?—E. C. WEAVER.

Many elementary chemistry textbooks show diagrams of the experiment of the burning of dry hydrogen in air. The water formed is condensed in an uncooled inverted beaker or under a bell jar. The water formed is shown to run down into a vessel below where it collects in *considerable* amount. In practice, the heat from the burning hydrogen warms this simple condenser to such an extent that only a little steam condenses to water. Are these diagrams unwarranted, or is some special technic needed to get amounts of water on such a condenser more than a mist?—E. C. WEAVER.

POLICY

The sponsors of this column will be glad to carry supplementary material which will be helpful to high-school teachers. We solicit questions, answers, helpful suggestions, items on educational advances, experiments, local activity news, and requests for material.

[1] Present address: Polytechnic High School, Long Beach, California.

SUMMER CONFERENCE OF THE NEW ENGLAND ASSOCIATION OF CHEMISTRY TEACHERS. PRELIMINARY ANNOUNCEMENT

The first summer conference, held last August at the University of Vermont, was so successful that the Executive Committee of the New England Association of Chemistry Teachers has voted to hold a second conference this summer. The meetings will be held on the campus of the University of Maine, Orono, Maine, on August 13, 14, 15, and 16, 1940. The morning and afternoon sessions will be devoted to topics of current interest pertaining to the teaching of chemistry in secondary schools and colleges and recent advances in scientific knowledge. Speakers of national reputation will participate. Meals and lodging will be provided at a very low rate by the University, and accommodations for families will be available. A social program, taking advantage of the location of the conference at one of the country's foremost vacation spots, is being planned.

The Committee in Charge is comprised of the following: Dr. Lawrence H. Amundsen, of the University of Connecticut; Professor Avery Ashdown, of the Massachusetts Institute of Technology; Professor Charles A. Brautlecht, of the University of Maine; Mr. Roscoe Dake, of Phillips Academy; Mr. Standish Deake, of Milton Academy; Mr. Everett F. Learnard, of Norwood Senior High School; Miss Eva Ruggli, of the Cambridge Latin School; and Mr. Theodore C. Sargent, of Swampscott High School, *Chairman*. The following officers of the association are also serving ex-officio: Mr. Ralph E. Keirstead, of Wethersfield High School, *President;* Professor Laurence S. Foster, of Brown University, *Vice-President;* and Mr. W. Davis Chase, of the New Britain High School, *Advertising Manager of the Report of the New England Association of Chemistry Teachers.*

There will be a registration fee of $2.00 for members in the association who register before August 1st, and $3.00 for those who register later than this date. Non-member teachers from New England, or elsewhere, who wish to attend, may do so by paying the usual membership fees of $3.00 for a full membership and $1.50 for an associate membership. Payment of a registration fee will not be required of members of the immediate family of teachers attending the conference.

For further information, a letter should be sent to Mr. Theodore C. Sargent, 834 Humphrey Street, Swampscott, Massachusetts.

RECENT BOOKS

MAY'S CHEMISTRY OF SYNTHETIC DRUGS. *Percy May*, D.Sc. (Lond.), F.I.C., Consulting Chemist and Chartered Patent Agent, and *G. Malcolm Dyson*, Ph.D., F.I.C., A.M.I.Chem.E., Chief Chemist, Genatosan Ltd. Fourth Edition. Longmans, Green and Company, London, New York, Toronto, 1939. xxxii + 350 pp. 5 figs. 14 × 22 cm. $6.00.

Those familiar with the third edition of this well-known work will welcome this joint effort, in which G. Malcolm Dyson, author of THE CHEMISTRY OF CHEMOTHERAPY (1928), collaborated. The need for a modern and reliable book in this field is acute, and hence this fourth edition will find wide use. Everyone will appreciate the senior author's sentiments when he writes in the preface,

"The third edition appeared seventeen years ago, but that edition differed only in minor respects from the two previous ones. Since then advances made in the subject-matter covered by the book have been enormous, but nevertheless the third edition has continued all the time to find favour with those for whom it was written. My satisfaction as author with such a state of affairs is, however, strongly tempered with regret that a book should be selling widely when its contents are so rapidly becoming out of date."

The present work is divided into eighteen chapters, *viz.*:

I. Introduction—the theory of the action of synthetic drugs.
II. The effect of various elements and radicles.
III. The chemical changes of drugs in the organism.
IV. Narcotics and general anesthetics.
V. Antipyretics and analgesics. (Derivatives of aniline and phenylhydrazine.)
VI. Alkaloids.
VII. Atropine and the tropeines—cocaine and the local anesthetics.
VIII. Morphine and the isoquinoline group of alkaloids.
IX. Ergot, adrenaline, and other derivatives of ethylamine.
X. The hormones and vitamines.
XI. Derivatives of phenol (antiseptics and anthelmintics).
XII. Other organic antiseptics excluding halogen compounds.
XIII. Halogen compounds.
XIV. Inorganic antiseptics and metallic compounds.
XV. Compounds of arsenic, antimony, and bismuth.
XVI. Purine derivatives (diuretics) and other uric acid eliminants.
XVII. Purgatives and other substances acting on the gastro-intestinal tract.
XVIII. Various other compounds of interest.

It will be quite obvious, especially to those interested in medicinal chemistry, that it is impossible to deal adequately and completely in three hundred fifty pages with the subjects indicated. In fact, the crying need in this field is a more comprehensive work, written and patterned somewhat after Gilman's ORGANIC CHEMISTRY but dealing more specifically with the chemistry of things medicinal. Not only is there incompleteness in May's fourth edition, but some will object to what has been sacrificed at the expense of much material which has been included. For example, the first three chapters (forty-two pages), which attempt to set forth the general principles of the relationship between structure and physiological activity, contain not a single bibliographical reference that is less than thirty years old. It is true that this book makes no pretense of giving a complete bibliography, and yet, especially since the authors regretted that the eighteen-year old third edition "should be selling widely when its contents are so rapidly becoming out of date," one expects basic conceptions to be modified in the light of recent developments. Or have we really made so little progress in this line that the work of the past thirty years may be practically ignored!

For the remainder of the book approximately eighty-five per cent. of the references are prior to 1920, while less than six per cent. are later than 1927 (Dyson wrote his CHEMOTHERAPY in 1928). It may be unfair to criticize the book because of its incomplete and somewhat ancient bibliography, but it is unfortunate that no mention is made of such recently developed items as, say, derivatives of thiobarbituric acid, local anesthetics of the piperidine type, neo-synephrin, merthiolate, and so forth.

The reader will be struck, for example, by the little attention given to developments in the United States. The authors presumably were oblivious of NEW AND NON-OFFICIAL REMEDIES, the annual publication of the American Medical Association, which serves chemists on this side of the Atlantic as a partial, conservative index to progress and advance in medicinal chemistry. Indeed, in the preface we read:

"The manufacture of synthetic organic chemicals on a large scale presents many difficult problems, and it is gratifying to find that most of these have been overcome successfully by British chemists."

Such an attitude may explain, among other things, why Thompson's name is not linked with the discovery of ergometrine (page 168), or why only passing mention is given to the excellent work now being carried out at Virginia on drug addiction (page 141) or to Williams' synthesis of vitamin B_1 (page 196). But it does not excuse the authors for various other editorial sins, such as, for example, completely ignoring Lamson's work on anthelmintics, for including the wrong structural formula for vitamin E (page 206), nor for erroneously stating (page 179) that in compounds of the epinephrine type "A phenolic hydroxyl group in the 3 position is about as active as in the 4 position. . . ."

In spite of such obvious deficiencies, the book deserves to be read; although it lacks completeness, it does contain much valuable information and presents an additional survey of the subject matter. The printing is excellent, and the errors are few. On page 123 appears a mistake in the empirical formula for beta-borocaine; on page 295 Loevenhart's name is misspelled while in the formula for *etharsanol* the aromatic ring should be attached to the nitrogen. In the diction, which is generally of high quality, one "Americanism" was observed (page 212) where it is stated that "None of these compounds *were* suitable. . . ."

WALTER H. HARTUNG

SCHOOL OF PHARMACY
UNIVERSITY OF MARYLAND
BALTIMORE, MARYLAND

INTRODUCTORY COLLEGE CHEMISTRY. *H. N. Holmes*, Oberlin College. Third Edition. The Macmillan Co., New York City, 1939, viii + 619 pp. 171 figs. 14.5 × 21 cm. $3.50.

Although the preface begins with the statement that this text has been written for the teacher who wants a book somewhat shorter and less difficult than the author's GENERAL CHEMISTRY, the difference between the two seems almost microscopic. The further implication that this text is as well suited to those who have had a preparatory course in chemistry as to those who are meeting the subject the first time is hardly warranted. The reviewer has yet to see the textbook which fulfills that specification.

INTRODUCTORY COLLEGE CHEMISTRY is, from many angles, a thoroughly good book for the beginner. It is *general* in its scope and treatment, *human* in its interest and appeal, and *balanced* in its emphasis and choice of material.

Its rather lengthy sections on organic chemistry, food and nutrition, photochemistry and nuclear reactions take it out of a class with the narrower texts on purely inorganic chemistry and make it particularly suitable for the general student whose formal introduction to the subject will not likely go beyond the first year.

It is in no sense a "scholarly" work. Its language is not pedantic; on the contrary colloquialisms are frequent. There are, of

course, a few careless slips, like the beginning sentence of the chapter on Nuclear Chemistry: "Lord Rutherford believes that Nuclear Chemistry is, in a sense, a new branch of knowledge."

The most outstanding characteristic of this, as well as the earlier editions of the author's texts, is their "middle of the road" policy. It may be assumed that this arises from the sincere conviction of the author, rather than the mere desire to sell more textbooks. Nevertheless, when one tries to please everybody he often ends by never completely satisfying anybody. The increasing tribe of chemical reformers may find this text too conservative; old timers and die-hards may find it too radical. The retention of such phrases as "practical molecule" and "effective fraction ionized" are examples of a desire for reconciliation rather than revolution. Its fundamental purpose seems to be to give the beginning student a sound and adequate enough theoretical knowledge of the nature of chemical phenomena to enable him to understand the practical ways in which chemistry is contributing to modern life and civilization.

Most teachers will probably approve of the distribution of emphasis between theoretical considerations and the practical chemical arts. The descriptions of industrial chemical processes are adequate without being boring. Among the particularly good features is the chapter on colloids, the author's specialty, certainly one of the best treatments of this subject to be found in any of our elementary textbooks.

On the other hand, it would seem that the importance of oxidation and reduction warrants a chapter heading, at least. As it is, any general study of this topic necessitates piecing it together from brief and widely separated paragraphs.

One can also agree with the author that the growing subject of photochemistry deserves a separate chapter, but at the same time wonder why he chose to hide the generally accepted name under the pseudonym of Radiation Chemistry.

The format of the book is the same as that of the earlier editions, except that the heavy cloth binding gives it a sturdier and more durable appearance. It is practical, both outside and in.

NORRIS W. RAKESTRAW

BROWN UNIVERSITY
PROVIDENCE, RHODE ISLAND

EINLEITUNG IN DAS STUDIUM DER CHEMIE. *Ira Remsen.* Translated and enlarged by *Dr. Hans Reihlen* of the University of Tübingen. Tenth Edition, completely rearranged. xv + 324 pp. 59 figs. 4 tables. 12 × 19 cm. Theodor Steinkopff, Dresden, 1939. Bound RM. 10.

A textbook which has undergone repeated revisions over a period of several decades may, in many respects, be likened to one of the cathedrals of the old world whose primitive design has undergone so many and such profound alterations with the passage of time that the casual visitor may fail to trace the surviving lines of the earlier structure among the more ornamental and arresting architectural features of a later period.

Shortly after completing his INTRODUCTION TO THE STUDY OF CHEMISTRY, Remsen in writing to his friend William Ramsay referred to his forthcoming book in these words, "It is somewhat on the plan of my organic chemistry, in this respect, that it deals rather fully with important matters, and but slightly with those which are less important, my belief being that in most courses in chemistry the mind is not allowed to dwell long enough on any one subject and to thus become acquainted with it, and that it is better to dwell longer on a few subjects, provided that these subjects be such as are well suited to give an insight into the nature of chemical activity."

This modest volume of barely five hundred pages measuring nine and one-half by fourteen centimeters was warmly received by American teachers of chemistry and very shortly was translated into several different foreign languages for use outside English-speaking countries.

Of these foreign editions the tenth German edition has just appeared from the pen of Professor Hans Reihlen of the University of Tübingen. This is an imposing volume of three hundred twenty-four pages and embraces between its covers the material required by the German universities in their "four-semester plan" for the study of general chemistry. To anyone who remembers the clear, concise language of the original text, this enlarged and more comprehensive volume will suffer by comparison. A close examination, however, reveals the retention by the translator of almost identical chapter headings as well as a method of presentation not essentially different from that followed by the originator of the book. Quite naturally much of the enlargement of the book is attributable to the rapid development of the science during the past fifty years which has necessitated the introduction of numerous new paragraphs, descriptive of the newer discoveries. In the present edition the author has entirely rearranged the discussion of such topics as coal, iron ores, and the silicates, while the section treating of the electromotive series has been throughly revised. New sections dealing with atomic structure, atomic disintegration and the separation of isotopes have been introduced, while in conformity with the so-called "four-semester plan," brief discussions of modern metallurgical operations have been added, together with descriptions of the methods of obtaining sulfur from coke-furnace gases and the separation of the heavier rare gases from the atmosphere. The description of more or less obsolete processes, such as those of Deacon, Weldon, and LeBlanc have been omitted, thus securing space for the consideration of topics of greater importance to the general student as well as to the prospective chemist.

The book in its latest form may be recommended as a thoroughly up-to-date, comprehensive treatise on general chemistry, while the typography and book-making leave nothing to be desired.

FREDERICK H. GETMAN

HILLSIDE LABORATORIES
STAMFORD, CONNECTICUT

THE WAVE NATURE OF THE ELECTRON. *G. K. T. Conn*, M.A., Ph.D. Chemical Publishing Co., New York City, 1938. iv + 78 pp. 12 × 18.5 cm. $1.50.

This little book has as its objective the description and interpretation to the general public of one of the most remarkable scientific advances of our time. That the attempt has not been entirely successful is understandable and is not so much a reflection on the author's ability as a writer on physical topics as a comment on the magnitude of the task he undertook. Dr. Conn is aware of the nature of the problem: "To steer between the Scylla of the obvious and the Charybdis of the specialized requires great care. . . ."

The book is divided into seven chapters: Electricity and the Electron, The Atomicity of Electricity, Particles and Waves, The Failure of the Particle Electron, The Wave Nature of the Electron I, The New Mechanics, The Wave Nature of the Electron II. While the material presented is entirely too sketchy to suit the "average reader," this book can be read with advantage by one who has a knowledge of elementary physics including atomic structure. Superior students who have been exposed to the physics part of a science "survey" course can probably profit enough from it to repay them for their efforts.

E. J. ROSENBAUM

THE UNIVERSITY OF CHICAGO
CHICAGO, ILLINOIS

PRACTICAL CHEMISTRY. *N. M. Shah.* The Students' Own Book Depot, Dharwar, India, 1938. Fourth Edition. vi + 66 pp. 14 × 21.5 cm.

A SURVEY OF COURSE OF STUDY AND OTHER CURRICULUM MATERIALS PUBLISHED SINCE 1934. *Bernice E. Leary.* U. S. Department of the Interior, Washington, D. C., 1938. v + 177 pp. 14 × 23 cm. $.20.

ANDREAS SMITS (1870–)

Prominent among the contemporary chemists of Holland is Andreas Smits, who since 1907 has directed the work in physical and inorganic chemistry at the University of Amsterdam. He was born June 14, 1870 at Woerden, Netherlands, and attended the universities at Utrecht, Amsterdam, and Giessen (Ph.D. 1896). His teaching career commenced at Utrecht, where he was assistant from 1890 until 1898 when he went to Amsterdam to continue his training in physical chemistry and thermodynamics under Roozeboom and van der Waals. In 1905 he was appointed Lector at Amsterdam, in 1906 he went to Delft as professor and in 1907 he came to his present chair as successor to Roozeboom.

His principal contributions, which are set down in a large number of papers by himself or with numerous students, may be classified into the chapters: Binary and ternary systems with critical endpoints; Retrogressive melting point lines; Allotropy of inorganic and organic substances; Transmutation; Complexity of so-called simple substances; Influence of intensive drying on the establishment of inner equilibria; Inner transformations in solid SO_3; Determination of the situation of the unary system in the pseudo-system SO_3; Pseudo-components; Low temperature transitions of ammonium halides and ND_4Cl, ND_4Br.

His "Die Theore der Allotropie" (1922) is available in English translation. He has assembled his ideas on the complexity of so-called simple substances in his recent (1938) book "Die Theorie der Komplexität und der Allotropie."

(Contributed by Ralph E. Oesper, University of Cincinnati)

EDITOR'S OUTLOOK

EDUCATIONAL MEASUREMENT. If the educational testers had accomplished nothing else, we owe them a debt of gratitude for debunking a considerable body of discussion of educational aims and ideals, and for discouraging further similar flights of fancy. At their best such discussions constituted beautiful literature, but in the mass they were essentially meaningless.

It was unfortunate, but probably inevitable, that some of the early activity in this field was of a nature well calculated to antagonize many sincere and capable practical teachers. Like all novelties, educational measurement attracted faddists whose enthusiasm outran their insight and general intellectual capacity. Widely accepted conclusions drawn from common observation were re-announced as significant new discoveries. Conclusions inadequately supported by the data submitted were drawn in rather dogmatic terms. Recommendations for educational practice were sometimes as much *non sequiturs* with respect to the conclusions drawn, as the conclusions were with respect to the experimental data reported.

From the standpoint of a casual observer who lays no claim to sound scholarship in this field, we believe that there has, however, been a trend toward improvement in the scientific value of the work done, toward increase in the significance of the problems undertaken, and toward the exercise of greater ingenuity in the attack upon problems of real significance. It is, therefore, with genuine respect for the present achievements of the testers, with an optimistic view to the future, and with the friendliest sentiments, we suggest that the whole of education may not be their province. Much of what we hope to accomplish by "education" has already been shown to be susceptible of measurement. It would be both short-sighted and pessimistic to assume that there will not be further improvements in present technics and further extensions of technic to other areas.

However, it would seem to the writer very unfortunate indeed if it were generally assumed that education involves no intangibles. It may be merely one more of the brutal facts of life that all educational achievement can be expressed in terms of graphs and charts, but we are reluctant to accept or to see others accept the dictum that the immeasurable does not exist.

REPRINTS OF JOURNAL ARTICLES. In response to many inquiries and requests from readers, the business management of the JOURNAL has now made reprints of current articles generally available. Type will be held until the fifteenth of the month of issue, and orders entered up to that time will be honored. Further details are presented in the advertising pages of this issue.

The Symposium on Theories and Teaching of Acids and Bases, presented on pages 124–36 of the March, 1940, issue, "Acid-Base Reactions in Non-Protonic Solvents," which appeared on pages 116–19 of the same issue, and "A Simplified Nomenclature for the Proton Transfer Concept of Acids," the Report of the Committee on Nomenclature of Acids and Bases, Division of Chemical Education, presented on pages 535–9 of the November, 1939, issue, are available in a combined reprint.

AUGUSTIN-PIERRE DUBRUNFAUT— AN EARLY SUGAR CHEMIST

HEWITT G. FLETCHER, JR.

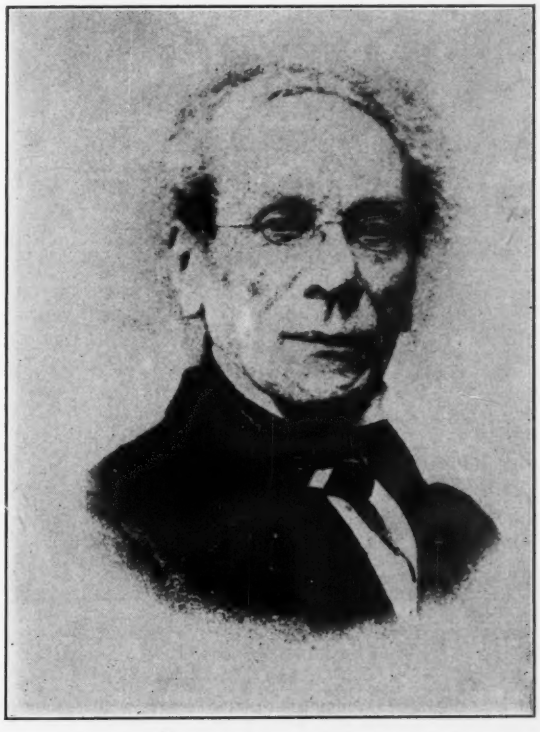
Massachusetts Institute of Technology, Cambridge, Massachusetts

AMONG the multitude of nearly forgotten founders of the modern sciences of sugar manufacturing and saccharimetry there is at least one man whose works deserve to be better remembered and appreciated. That man is Augustin-Pierre Dubrunfaut, the discoverer of mutarotation, of fructose, and one of the first investigators of maltose. He was born September 1, 1797, at Lille where he first attended school and received a good classical education. Later he worked at Lille under Drappiez and Delezenne in physics and chemistry and finally completed his education at the Faculté des Sciènces at Paris where he worked under such well-known chemists as Thénard, Gay-Lussac, Dulong, and Pouillet. One of his first investigations was on the diastatic action of an infusion of malt on starch and in 1823 he was awarded the gold medal of the Société Central d'Agriculture for his paper on the saccharification of starch. From 1824 to 1830 he held a professorship in applied chemistry and physics at a technical school in Paris. At the same period, in 1827, he founded at Bercy, a suburb of Paris, a school for beet-sugar manufacturing. In 1830 he directed a beet-sugar factory as a school at La Varenne-Saint Maur and at about the same time he managed an agricultural distillery at the Ménagerie de Versailles.

About the personal history of the man there seems to be little information. He was, however, known as an ardent hobbyist, having made a study of the French Revolution. During the latter part of his lifetime he attempted to collect the autographs of all the members of the Convention Nationale, and at the time of his death the collection numbered six hundred ninety-two pieces. It is said that he liked the autograph collection the best, although it formed but a seventh part of his collection on the French Revolution (*1*).

During his lifetime he was very active as an industrial chemist as well as an investigator. Not only did he found at Douai a plant for the production of alcohol from beet sugar, but he was constantly employed in writing on practical matters concerning the sugar and alcohol industries. At the comparatively early age of twenty-seven he published his "Traité complet de l'art de la distillation" which was indeed a "complete" work, containing in three parts a comprehensive survey of the available information. The first part dealt with the various sources of sugar and the means for preparing these materials for fermentation, the second part treated the technic of fermentation, while the third concerned the distillation of the alcohol formed. The work, in two volumes, includes many passages of historical interest. That Dubrunfaut had a clear and surprisingly modern understanding of political economy is evidenced by his opening remarks in this work.[1]

"Considérée d'une maniére absolue, toute opération qui change la forme des choses pour augmenter leur valeur est une véritable production; considérée d'une manière relative, c'est une



AUGUSTIN-PIERRE DUBRUNFAUT (1797–1881)

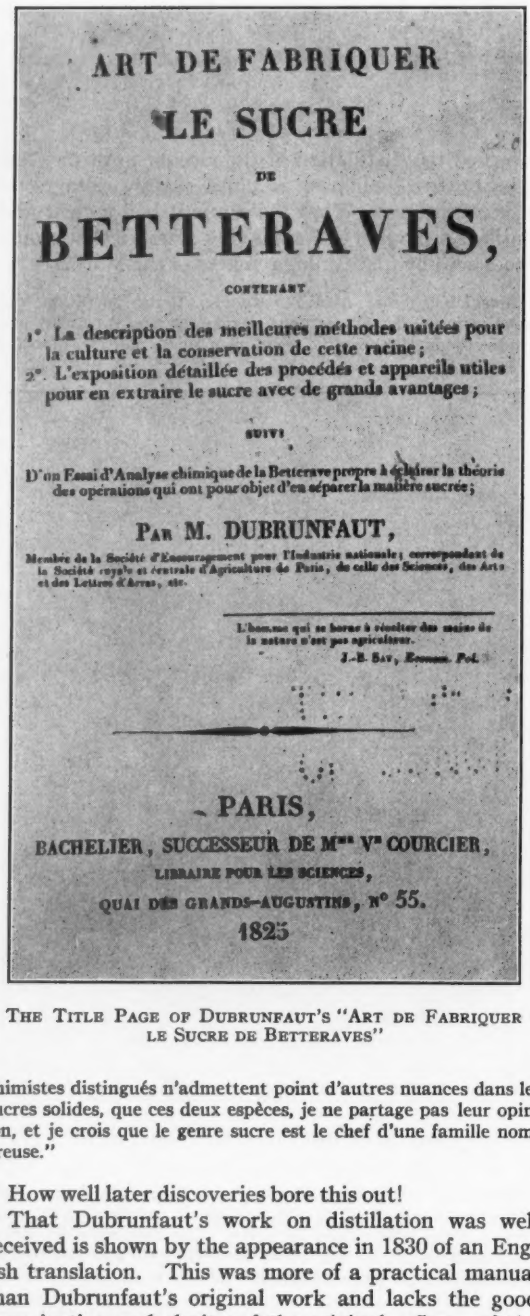
richesse d'autant plus grande pour une nation que la nouvelle production comporte plus d'importance et qu'elle s'exerce elle-même sur des productions indigènes. Ces axiomes d'économie politique trouvent ici leur place naturelle. Ce sont des vérités incontestables que je vais consolider par des examples."

It is indeed surprising to notice Dubrunfaut's per-

[1] "Traité complet de l'art de la distillation," Bachelier, Paris, 1824, Vol. I, p. 1.

spicacity when, speaking of different kinds of sugar, he says,[2]

"Une grand nombre d'extraits de végétaux peuvent aussi fournir un sucre qui se rapproche plus ou moins de l'un ou l'autre des deux espèces que nous venons de signaler; et quoique plusieurs


ART DE FABRIQUER
LE SUCRE
DE
BETTERAVES,
CONTENANT
1°. La description des meilleures méthodes usitées pour la culture et la conservation de cette racine;
2°. L'exposition détaillée des procédés et appareils utiles pour en extraire le sucre avec de grands avantages;
SUIVI
D'un Essai d'Analyse chimique de la Betterave propre à éclairer la théorie des opérations qui ont pour objet d'en séparer la matière sucrée;
PAR M. DUBRUNFAUT,
Membre de la Société d'Encouragement pour l'Industrie nationale; correspondant de la Société royale et centrale d'Agriculture de Paris, de celle des Sciences, des Arts et des Lettres d'Arras, etc.
L'homme qui se borne à résulter des mains de la nature n'est pas agriculteur.
J.-B. SAY, Econom. Pol.
PARIS,
BACHELIER, SUCCESSEUR DE Mme Ve COURCIER,
LIBRAIRE POUR LES SCIENCES,
QUAI DES GRANDS-AUGUSTINS, N° 55.
1825

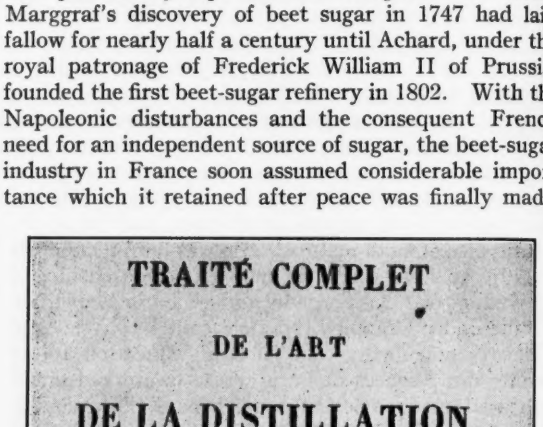
THE TITLE PAGE OF DUBRUNFAUT'S "ART DE FABRIQUER LE SUCRE DE BETTERAVES"

chimistes distingués n'admettent point d'autres nuances dans les sucres solides, que ces deux espèces, je ne partage pas leur opinion, et je crois que le genre sucre est le chef d'une famille nombreuse."

How well later discoveries bore this out!

That Dubrunfaut's work on distillation was well received is shown by the appearance in 1830 of an English translation. This was more of a practical manual than Dubrunfaut's original work and lacks the good organization and clarity of the original. Some of the best parts of the French work have been deleted while a large section of receipes for alcoholic drinks has been added.

In 1825, the year after his work on distillation, his second and most important work was published. It was the "Art de fabriquer le sucre de betteraves"—a work destined to prove useful and influential in the beet sugar industry for over fifty years (*2*). The time was particularly ripe for this comprehensive work. Marggraf's discovery of beet sugar in 1747 had lain fallow for nearly half a century until Achard, under the royal patronage of Frederick William II of Prussia, founded the first beet-sugar refinery in 1802. With the Napoleonic disturbances and the consequent French need for an independent source of sugar, the beet-sugar industry in France soon assumed considerable importance which it retained after peace was finally made


TRAITÉ COMPLET
DE L'ART
DE LA DISTILLATION,
CONTENANT, DANS UN ORDRE MÉTHODIQUE,
Les instructions théoriques et pratiques les plus exactes et les plus nouvelles sur la préparation des liqueurs alcoholiques avec les raisins, les grains, les pommes de terre, les fécules et tous les végétaux sucrés ou farineux;
PAR M. DUBRUNFAUT,
Membre de la Société d'Encouragement pour l'industrie nationale, et Auteur d'un Mémoire sur la Saccharification des fécules, couronné, en 1823, par la Société royale et centrale d'Agriculture de Paris.
TOME PREMIER.
PARIS,
BACHELIER, LIBRAIRE (SUCCESSEUR DE Mme Ve COURCIER),
Quai des Augustins, n° 55.
1824.

THE TITLE PAGE OF A.-P. DUBRUNFAUT'S "TRAITÉ COMPLET DE L'ART DE LA DISTILLATION"

It was Dubrunfaut who first gathered and ordered the accumulated information in a book.[3]

[2] Traité complet de l'art de la distillation," Bachelier, Paris, 1824, Vol. I, p. 245.

[3] For an interesting account of this book see E. O. VON LIPPMANN, "Vor hundert Jahren IV," *Deut. Zuckerind.*, 50, 17–18 (Jan., 1925).

In 1845 Dubrunfaut published "La vigne remplaceé par la betterave pour la production des alcools"—a work which is said to have had almost immediate and far-reaching effect upon the French alcohol industry (*3*). He himself carried out many new ideas by founding in 1858 at Chalon-sur-Saône a factory for the direct production of alcohol from sugar beets.

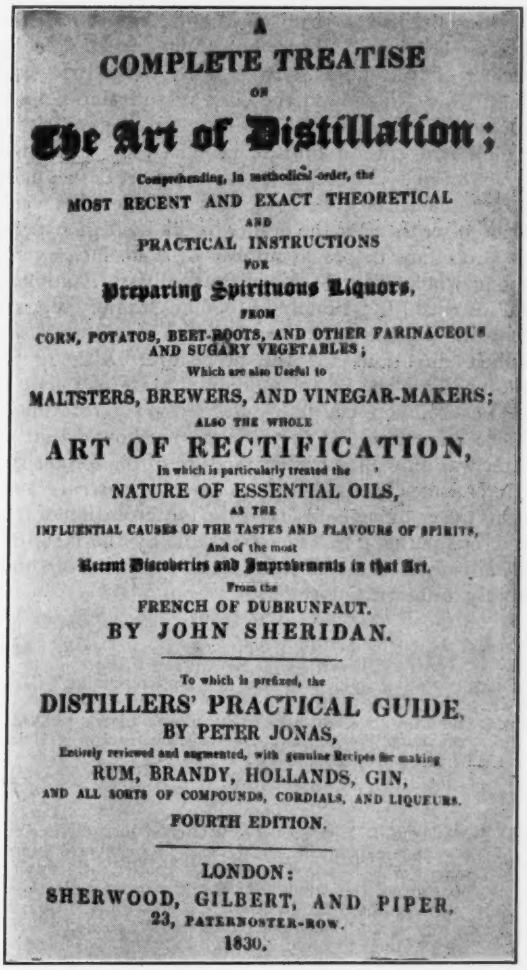
Like other scientists of his time he did most of his researches with very practical ends in view. For his work on the refining of sugar by means of its barium salt he was awarded two council medals by the London Exposition of 1851. The same exposition also awarded him a First Class medal for his process of concentrating acids by distillation.

He collaborated in the writing of such publications as *l'Industriel, Revue encyclopédique, l'Encyclopédie moderne* and was editor of a number of agricultural chemical works—notably of the *Bulletin universel des sciences*. In 1830 and 1831 he published *l'Agriculteur manufacturier*, one of the first important publications having articles on the beet-sugar industry. He also wrote considerably on the commercial applications of osmosis.[4] For a number of years notes and articles from his scientific investigations were published in the *Comptes rendus* of the French Academy of Sciences. His works may also be found in *Annales de chimie et physique* while translations of some of these French articles appeared in *Erdmann's Journal für Praktische Chemie*.

He was a member of numerous scientific societies and a Knight of the Legion of Honor.

Dubrunfaut's most notable contribution to organic chemistry was his discovery of mutarotation (*4*). He first observed this phenomenon in 1846 during a study of the optical inversion of cane sugar as a means of analysis. Obtaining from Soleil a polarimeter, then a newly invented instrument, he began an investigation to determine the temperature coefficients and inversion constant. Before he was well under way, however, his work was anticipated by Clerget who published his well-known work on the inversion of sucrose. But one new thing that Dubrunfaut did observe was that freshly dissolved glucose had a rotational value twice that which Biot had observed. Later Dubrunfaut called this phenomenon "birotation" because the final value for glucose was about half the original one (*5*).

As has often happened in the past with great discoveries this one made little impression upon Dubrunfaut's contemporaries. He himself continued his researches, looking for mutarotation among other sugars. The second case he studied was that of lactose where he found a change of from 8/5 to 1 (*5*). Always he attempted to find some simple numerical relationship between the initial and final rotations. During Dubrunfaut's lifetime many theories were advanced to explain mutarotation—a phenomenon which at that stage of science was quite incapable of explanation. Béchamp, for instance, suggested that it might be due to hydration of the sugar, but Dubrunfaut disproved this by studying carefully the mutarotation of anhydrous and hydrated glucose (*6*). A truly skeptical scientist, Dubrunfaut himself was very cautious in his statements regarding the cause of mutarotation. He only supposed it to be a manifestation of an entirely general change which takes place when solids are dissolved. In support of this he showed that there is a difference between the initial and final solubilities of lactose (*6*). The true explanation of the phenomenon was not, of course, to come until the turn of the century, long after Dubrunfaut's death.


A
COMPLETE TREATISE
ON
The Art of Distillation;
Comprehending, in methodical order, the
MOST RECENT AND EXACT THEORETICAL
AND
PRACTICAL INSTRUCTIONS
FOR
Preparing Spirituous Liquors,
FROM
CORN, POTATOS, BEET-ROOTS, AND OTHER FARINACEOUS AND SUGARY VEGETABLES;
Which are also Useful to
MALTSTERS, BREWERS, AND VINEGAR-MAKERS;
ALSO THE WHOLE
ART OF RECTIFICATION,
In which is particularly treated the
NATURE OF ESSENTIAL OILS,
AS THE
INFLUENTIAL CAUSES OF THE TASTES AND FLAVOURS OF SPIRITS,
And of the most
Recent Discoveries and Improvements in that Art.
From the
FRENCH OF DUBRUNFAUT.
BY JOHN SHERIDAN.
To which is prefixed, the
DISTILLERS' PRACTICAL GUIDE,
BY PETER JONAS,
Entirely reviewed and augmented, with genuine Recipes for making
RUM, BRANDY, HOLLANDS, GIN,
AND ALL SORTS OF COMPOUNDS, CORDIALS, AND LIQUEURS.
FOURTH EDITION.
LONDON:
SHERWOOD, GILBERT, AND PIPER,
23, PATERNOSTER-ROW.
1830.

THE TITLE PAGE OF THE ABRIDGED ENGLISH TRANSLATION OF A.-P DUBRUNFAUT'S "TRAITÉ COMPLET DE L'ART DE LA DISTILLATION"

Concerning the importance of the discovery of mutarotation C. S. Hudson says:[5] "This discovery (Tanret's of the two forms of

[4] DUBRUNFAUT, "L'Osmose et ses applications industriel," Paris, 1873.

[5] *J. Am. Chem. Soc.*, **32**, 889 (1910).

glucose) is the complement of Dubrunfaut's and the two must cause chemists the world over to be grateful to French science, because more fruitful single discoveries in the chemistry of the carbohydrates have hardly been made."

He was a member of numerous scientific societies and a Knight of the Legion of Honor.

Dubrunfaut's second most important discovery was that of fructose. He early recognized that invert sugar was a mixture of two sugars and in 1847 he isolated (*7*) the insoluble lime addition compound of fructose from which on careful treatment with oxalic acid he obtained a sirup of fructose which he called "glucose lévogyre." Later he obtained fructose from a number of fruit juices as well as by the hydrolysis of inulin (*8*). He showed the close relationship between glucose and fructose by measuring the quantities of alcohol and carbon dioxide produced by each upon fermentation. At the time there was great scepticism among scientists concerning his discovery. Over a period of years after the original work he demonstrated the procedure before a number of doubting savants, among whom were Melsens, Stas, Bussy, Kuhlmann, and Magnus (*9*). Finally in 1856 he carefully repeated his work on the isolation of fructose and published explicit directions for the procedure. Although he obtained fructose in an undoubted state of purity he was never able to crystallize it. From the rotations of glucose, fructose, and invert sugar he showed that the latter was an equimolecular mixture of the former two.

It is somewhat odd that so keen an observer as he seems never to have observed the mutarotation of fructose, but perhaps this is explainable by the facts that he had only a sirup and that fructose is one of the most rapidly mutarotating sugars.

Dubrunfaut should be remembered as one of the first to isolate and characterize the disaccharide maltose. DeSaussure in 1819 (*10*) had obtained maltose in a very doubtful state of purity, and it is questionable whether he recognized it as a single compound. In 1847, however, Dubrunfaut isolated a compound from the diastatic reaction of malt on starch and named it maltose (*11*). Here, again, although he took the specific rotation of his product he appears to have missed completely its mutarotation. Like DeSaussure's discovery, Dubrunfaut's was completely forgotten, and it remained for O'Sullivan in 1872 (*12*) to rediscover this important sugar.

On October 7, 1881, Dubrunfaut died at Bercy—a renowned industrial chemist and teacher, famous for his contributions to the beet-sugar and alcohol industries of France but even himself never aware of the importance of his discovery of mutarotation. His burial was in harmony with the tenor of his life, for he decreed in his will that his funeral should be simple and quiet, the expenses which would have gone to the usual flowery affair to be given to the poor.[6]

ACKNOWLEDGMENT

The writer wishes to express his sincere appreciation to Professor E. O. von Lippmann for his kind aid in finding a photograph of Dubrunfaut. To Professor R. C. Hockett and Professor T. L. Davis, both of the Massachusetts Institute of Technology, he also wishes to make grateful acknowledgment for innumerable kind suggestions.

[6] DAVIS, "Dubrunfaut and His Work, 1797–1881," *Chemistry & Industry*, **49**, 644 (1930). This is an excellent sketch of his life as well as a particularly valuable review of his chemical works.

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(3) See Glaeser, cited above.

(4) *Compt. rend.*, **23**, 42 (1846); *Ann. chim. phys.*, **18**, 99–107 (1846); *ibid.*, **21**, 178–80 (1847).

(5) *Compt. rend.*, **42**, 228 (1856).

(6) *Ibid.*, **42**, 739 (1856).

(7) *Ibid.*, **25**, 308 (1847).

(8) *Ibid.*, **42**, 739 (1856).

(9) *Ibid.*, **42**, 901 (1856).

(10) *Ann. chim. phys.*, **11**, 379 (1819).

(11) *Ibid.*, **21**, 178 (1847).

(12) *Ber.*, **5**, 485 (1872).

SPRING MEETING OF THE ILLINOIS ASSOCIATION OF CHEMISTRY TEACHERS

The annual Spring Meeting of the Illinois Association of Chemistry Teachers will be held at Springfield, Illinois, on Saturday, April 6, 1940. The morning session will be devoted to inspection trips to two of the newest state laboratories, the highway and bacteriological units. The luncheon and afternoon business and professional program will be held at the Springfield Junior College. Dr. John C. Hessler, James Millikin University, President of the Association, will preside.

A PHYSICAL SCIENCE GENERAL COURSE *for* GRADES 11 *and* 12[1]

THEODORE A. ASHFORD

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INTRODUCTION

IN RECENT decades, the influx of our population into the high schools and colleges has inaugurated a movement in the direction of replacing specialized training by liberal or general education. Largely in response to this situation, the University of Chicago in 1931 put into effect the "New Plan," an essential part of which was the development of general courses in the fields of the physical sciences, the biological sciences, the social sciences, and the humanities. These courses have been in operation since the introduction of the New Plan, and are taken by the students of the university in their freshman or sophomore years.

Meanwhile, the University of Chicago has entered a more comprehensive program in integrating education. A four-year college has been organized, which consists of the two upper grades of the high school, *i. e.*, grades 11 and 12, and the two lower years of the university, *i. e.*, grades 13 and 14. Since the autumn of 1936 general courses are being developed for the grades 11 and 12. In the physical sciences, the general course now developed, replaces high-school physics and high-school chemistry. This course extends over a period of two years, and may be taken as an alternative to the physical science general course of the thirteenth year.

OBJECTIVES OF THE COURSE

In a single sentence the objective of the course has been stated as follows: To provide the student the opportunity to obtain a unified picture of the physical universe which should contribute to the development of a rational philosophy of life.

This objective may be expressed operationally in terms of the following more specific understandings and attitudes which the student should develop.

(1) Understanding of the nature of matter and its transformations.
(2) Understanding of the nature of energy and its various manifestations.
(3) Understanding of the distribution of matter and energy in the vast cosmic space.
(4) Understanding of the changes that are taking place on the surface of the earth, and the important events that have taken place during the enormous span of geologic time.
(5) Understanding of some important aspects of everyday experience, including developments in applied science, in terms of a fundamental system of laws and generalizations.
(6) Understanding and appreciation of the methods used in gaining knowledge in the various fields of science.
(7) Development of a rational attitude of mind.
(8) An appreciation of the relation of man to the physical universe.

The course has been developed with these objectives in view. In order to indicate what provisions have been made for the attainment of these objectives, the content of the course, the methods of approach, and the methods of instruction will be briefly discussed.

OUTLINE OF THE COURSE

The course is an integration of physics, chemistry, astronomy, and geology. For pedagogical purposes the subject matter has been organized around seventeen areas or units, eight of which are taught during the first (eleventh) year and the remaining nine during the second (twelfth) year. For each year a one hundred twenty page syllabus is available, in which the contents are developed in detail, and which serves as a guide for study. A brief statement about each unit will give a fair idea of the scope of the course.

First Year

The Earth, Our Home is a general discussion of the size, shape, motions, constitution, and main surface features of the earth as the abode of man.

The Ever Changing Face of the Earth is a study of weather and the geologic processes, gradation, diastrophism, and volcanic activity.

Motion is an analytical study of uniform and accelerated motion from the point of view of Newton's laws of motion.

Energy, the Agent of All Change is a study of the various forms of energy, mechanical as well as heat, its transformations and the law of its conservation.

The Molecular Nature of Matter is a study of the behavior of matter in the gaseous, liquid, and solid states, and in solution, and the interpretation of this behavior in terms of the kinetic molecular theory.

The Atomic Constitution of Matter is a study of the

[1] Presented before the Division of Chemical Education at the ninety-sixth meeting of the A. C. S., Milwaukee, Wis., September 7, 1938.

nature of chemical change, the laws of chemical combination, and their interpretation in terms of atomic theory.

Electricity, at Rest and in Motion is a study of fundamental phenomena in magnetism, static electricity, and current electricity.

The Electrical Nature of Matter is a study of the phenomena which lead to the idea of the atomic nature of electricity and to the concept of the Rutherford atom.

Second Year

The Chemical Reaction is a study of combustion and other chemical reactions, the energy changes during a reaction, the speed of a chemical reaction, and the concept of chemical equilibrium.

Atomic Structure and Chemical Behavior is a study of the periodic arrangement of the elements on the basis of chemical evidence on the one hand and physical evidence on the other, and the relation between electron configuration and chemical behavior.

Ions and Ionization is a study of electrical properties of solutions, the classification of ionogens into acids, bases, and salts, ionic equilibria, and oxidation-reduction in solution.

Metals and Non-Metals is a systematic study of the most important metals and non-metals on the basis of general relationships in the periodic system.

Carbon, the Element of Life is a study of the most important characteristics of organic compounds, particularly the relation between molecular architecture and chemical properties.

The History of the Earth is a study of the methods of estimating the age of rocks, and a brief account of the most important biological and physical events of the geologic past.

The Earth and Its Neighbors is a study of the earth and other members of the solar family, and the dynamics, structure, and possible origin of the solar system.

Waves as Carriers of Energy is a study of wave motion, sound, and the wave characteristics of radiant energy over the entire range of the electromagnetic spectrum.

Atoms and Stars is a study of spectra, and their use in determining the nature of the stars, their distribution in space, and the structure of the siderial universe.

Even from this brief outline it may be seen that there is considerable integration. For each unit the material is drawn from all sciences as needed, with the definite effort to arrange it according to difficulty. The first two units contain essentially descriptive material, taken mainly from astronomy and geology. The units on mechanics are considerably more difficult, but are introduced early in order to build a logical structure of science. The units on molecular theory, atomic theory, and atomic structure are examples of integration of physics and chemistry. The same plan is followed in the units of the second year, into which the more difficult topics of modern physics are woven. This arrangement makes constant review not only desirable but necessary.

METHODS OF APPROACH

Throughout the entire course the scientific method is used, though no provision is made to teach a formal branch of logic. The experimental material is presented and certain problems are raised. In order to solve these problems correlations are made, and several hypotheses are advanced. The deductions from these hypotheses are tested experimentally, so that some hypotheses are discarded while others are tentatively accepted. In this manner, the accepted theories and generalizations of science are developed and evaluated in terms of the evidence that supports them.

Whenever feasible, the historical approach is used. This approach has an important cultural value, and gives a better appreciation of the development of science. Science is taught not as a finished product, but as an evolving, growing, living thing.

Although, as is evident from the foregoing discussion, the principles of science are emphasized, nevertheless applications are freely used. The explanation of phenomena of everyday experience is an important objective of the course. To use a metaphor, while principles form the supporting skeleton of the structure of science, applications are the flesh. Moreover, because of the immediate relation to experience, applications aid in the understanding of the principles. The frequent use of applications makes the principles more meaningful so that the knowledge obtained functions in the lives of the students.

METHODS OF INSTRUCTION

The course consists of four class periods per week and one double laboratory period. During the class periods instruction is carried on by means of lectures and supervised study. The lectures are supplemented with demonstration experiments, motion picture films, and slides.

The demonstration experiments are an integral part of the lectures. In all stages of the development of the unit, experiments are performed, which in every case constitute the basis upon which the ideas are built. In general, the experiments are qualitative rather than quantitative in character. The apparatus is chosen to make them as simple as possible, the object being to elucidate the fundamental ideas without complicating the issue with extraneous refinements. For example in showing that metals gain weight on heating in air, a steel or a wooden beam, balanced from the center, is to be preferred to an expensive analytical balance. Whenever possible instances from everyday life are used.

In addition to the demonstrations, the student performs a number of experiments individually. The function of this laboratory work is to provide the student the opportunity to come in contact with the raw materials of science and to develop the ability to plan his own course of action. From a list of problems, which require experimentation for their solution, the student selects one or more. Detailed directions are not given but the problems are such that they require a minimum

of manipulative skill. For example, in chemistry the problem may be to determine whether a given acid is strong or weak, which may be solved in a variety of ways.

A series of sound films for general courses in physical sciences has been developed by the Erpi Picture Consultants, Inc., in coöperation with The University of Chicago. These contain well integrated and highly concentrated material. They are used as a part of the presentation in the beginning of the unit, and as a summary at the end. In addition to these films, other well-known films on special topics (*e. g.*, on petroleum) are shown. Throughout the entire course, but more commonly in topics on geology, astromony, and organic chemistry, numerous slides are used in connection with the lectures. They provide illustrative material in fields in which first-hand contact is physically impractical.

During the year several museum trips are taken. Among the museums visited are the Adler Planetarium, the Rosenwald Museum, and the several museums of the University. The function of the museum trips is twofold: to provide instruction on phases of science in which the several museums are specifically equipped, and to develop a rich background of experience. It is hoped that as a by-product the trips would help develop a life-long interest in the cultural aspects of science. In addition to the class trips, assignments are given which require independent visits by the student. From a list of topics to be investigated the student selects one or more, visits the museum at hours suitable to his individual program, and makes a written or oral report.

A special effort is made to develop an interest in independent reading of science material. A wide variety of library projects is provided, from which the student selects from one to four per month. These projects may be either essentially extensive material of slight difficulty, such as biographies of men of science, tracing the development of ideas, or description of industrial processes; or they may require intensive study of some particular topic. The student makes either a written or an oral report on his study.

EVALUATION OF THE COURSE

Progress in the four-year college is determined by passing the various comprehensive examinations. A student may satisfy the requirements for the physical sciences by passing either the comprehensive examination for the course given in the thirteenth year, or two comprehensive examinations, one at the end of each year of this two-year course.

The examinations for the course of the thirteenth year have been taken by over four thousand students in the past eight years. By this time they are fairly well standardized, as shown by the fact that for the past four years the mean has not varied by more than three per cent. As the two courses are essentially equivalent, and a large amount of material is common to both, it is possible to obtain a comparison by including common items in the comprehensive examinations. From the examinations given in June, 1938 the following comparisons have been obtained.

TABLE 1

	Two-year course		*One-year course*
	11th year	*12th year*	*13th year*
Number taking the examination	116	31	542
Maximum score obtainable	270	218	413
Mean score	177	160	274
Per cent. of total	65.6%	72.0%	66.3%
Common items between 11th and 13th	67	—	67
Mean score on common items	41.2	—	41.0
Per cent. of total	61.5%	—	61.2%
Common items between 12th and 13th	—	130	130
Mean score on common items	—	98.6	81.0
Per cent. of total	—	77.4%	62.3%

The results indicate that the achievement of the younger groups is as high, if not higher, than that of the older groups. This conclusion confirms the definite impression which the author has developed as a result of personal contact with groups in each course. It seems that the more time spent by the younger groups under better supervision more than counterbalances their immaturity.[2]

It might be pointed out that for a person studying at The University of Chicago, taking the course in the eleventh and twelfth years rather than attending a regular high school is a significant saving of time. The average student taking the physical science general course in his freshman (or sophomore) year in the university during 1937–1938, had spent 1.21 years in high-school physics and chemistry. That is, the student will have spent 2.21 years before he fulfils the physical science requirements. By taking the two-year course the same requirements are completed in two years by the end of the twelfth year.

The author wishes to express his indebtedness to Dr. Marion W. Richardson, of the Board of Examinations, for supplying the data from the examinations, and to his colleagues, Mr. Clifford Holley and Dr. Selby M. Skinner, for their contributions to the development of the course.

[2] During the academic year 1938–39 there were three classes taking the first-year course and three classes taking the second-year course. An analysis of the comprehensive examination of June, 1939, shows no statistically significant differences in the achievement of these groups, compared to that of the thirteenth year group.

FLUORSPAR—ITS CHEMICAL *and* INDUSTRIAL APPLICATIONS

LENHER SCHWERIN

General Manager, Victory Fluorspar Mining Company, Elizabethtown, Illinois

The history and properties of fluorspar are briefly outlined.

The occurrence of fluorspar and the genesis of bedding replacement deposits are discussed.

The use of fluorspar as a metallurgical flux because of its remarkable effect in decreasing the viscosity of basic slags is described. The results of the author's research in that field are outlined.

It is pointed out that fluorspar is the chief economic source of fluorine in hydrofluoric acid and all fluorine compounds used in or produced by the chemical industry. The uses of the principal compounds are given.

Another important use of fluorspar, in ceramics, is presented.

A new rapid method for the chemical analysis of fluorspar is suggested.

✦ ✦ ✦ ✦ ✦ ✦

PROPERTIES OF FLUORSPAR

FLUORSPAR has long been used as a flux in metallurgical operations, its name being derived from the Latin *fluo, fluere,* to flow, in recognition of its low melting point and liquidity when molten. Agricola (*1*) as early as 1556 recognized three classes of "stones which easily melt in the fire" called *fluores* or *schöne flüsse* by the miners of that day, who added them to the ores which they smelted, "for by the heat of fire, like ice in the sun, they liquefy and flow away." Although minerals had not then been scientifically classified, from Agricola's description of the first class, which "are not only transparent, but are also resplendent, and have the colors of gems, for some resemble crystal, others emerald, heliotrope, lapis lazuli, amethyst, sapphire, ruby, and so forth, and other gems, but they differ from them in hardness," it is evident that he referred to fluorspar. It has an unusual characteristic of occurring in all colors met with in the mineral kingdom, but its relative softness and cleavability make it of little value as a gem.

CRYSTAL PROPERTIES OF FLUORITE

In this country it is usual to refer to the mineral by itself as fluorite and to the ore as fluorspar. The chemical composition of fluorite is calcium fluoride, CaF_2, and its melting point is 1378°C. It crystallizes in the isometric system, with face-centered cubic lattice, each fluorine atom surrounded by four calcium atoms and each calcium atom by eight fluorine atoms (*2*). It exhibits perfect octahedral cleavage. Its crystal habit is apparently influenced by the mode or temperature of its origin (*3*). Usually it is found in the form of simple cubes or interpenetration twins in which the cubes are arranged symmetrically about a face of the octahedron (Figure 2). The simple forms seem to be derived from hydrothermal origin, that is, precipitation from warm aqueous solutions. Octahedral and more complicated forms apparently form at higher temperatures by reaction of the vapor phase, known geologically as pneumatolytic processes. The writer has obtained, by slow crystallization of a melt of the pure material, dendrites exceedingly rich in crystal faces which have not been observed in nature.

Fluorite has the property of decrepitating or violently flying to pieces when heated to 200° or 300°C. This led the writer some years ago to suspect an allotropic transformation accompanied by volume change. However, accurate density determinations showed an average decrease from 3.182 to only 3.180, and X-ray spectra showed that lattice expansion was too slight to be significant. It was determined that fluorite crystals usually contain water which is driven off with disruptive force when heated rapidly.

FLUORESCENCE

The phenomenon of fluorescence derives its name from fluorite, the first mineral in which this effect was observed. As Wooster (*3*) expresses it, "The colour of a given specimen often varies with the way in which light falls on it. Thus many green-blue specimens are green by transmitted light and blue by reflected." Furthermore, certain colored varieties of fluorite glow with a vivid green-blue light when irradiated with invisible ultra-violet light. The character of the emitted light depends upon the crystal specimen and the wavelength of the irradiation. The fluorescence and color of fluorite have been determined to be due to impurities such as manganese, the rare earths, and radioactive material. Pure fluorite will not fluoresce. Exceedingly minute quantities of these impurities suffice to give the above effects, by imparting their characteristic colors as pigments, by scattering action resulting from their fine state of division and dispersion (*4*) much as

colloidal gold may appear either red or blue, or by radioactive radiations of β- and γ-rays.

Fluorite also exhibits thermoluminescence, that is, when heated to 40–80°C. the crystals glow, the light being visible in a darkened room.

OCCURRENCE OF FLUORSPAR AND GENESIS OF BEDDING REPLACEMENT DEPOSITS

Although fluorspar is widely distributed in igneous rocks, its occurrence in commercial quantities is distinctly limited. In this country it is mined on a small scale in Colorado, New Mexico, and Arizona, but the

FIGURE 1.—VICTORY MINE AND MILL

large center of production is a small area in southern Illinois and across the Ohio River in Kentucky, where it occurs in bedding replacement deposits and in veins in sediments (limestone, sandstone, and shale) of Carboniferous age. The deposit operated by Victory Fluorspar Mining Company is a replacement of the limestone, the banding of the ore, typically illustrated in Figure 3, being a relict structure due to physical and chemical differences in the layers of the original limestone resulting from seasonal changes while it was being laid down. The comb structure of pure bands is due to a decrease of volume, the CaF_2 molecule being more dense than the $CaCO_3$ molecule which is replaced. The presence of inclusions of iron sulfide (Figure 2) in the form of orthorhombic marcasite rather than isometric pyrite indicates that the solutions which brought in the fluorine were acid and at low temperature. Currier (*5*) has proposed the following chemical equations to explain the precipitation of CaF_2 *in situ* and the reorganization of the silica:

$$2HF + CaCO_3 \longrightarrow CaF_2 + H_2O + CO_2$$

$$4HF + SiO_2 \longrightarrow SiF_4 + 2H_2O$$

$$SiF_4 + 2CaCO_3 \longrightarrow 2CaF_2 + SiO_2 + 2CO_2$$

The present writer has found that an aqueous ten per cent. solution of NaF at room temperature for three days will react with limestone and coat it with CaF_2 and suggests, therefore, that the reaction be made more general as involving the fluoride ion, as follows:

$$2F^- + CaCO_3 \longrightarrow CaF_2 + CO_3^=$$

The above reactions seem to explain satisfactorily the metasomatic replacement of the limestone, whereby a molecule of CaF_2 is deposited in place of a molecule of

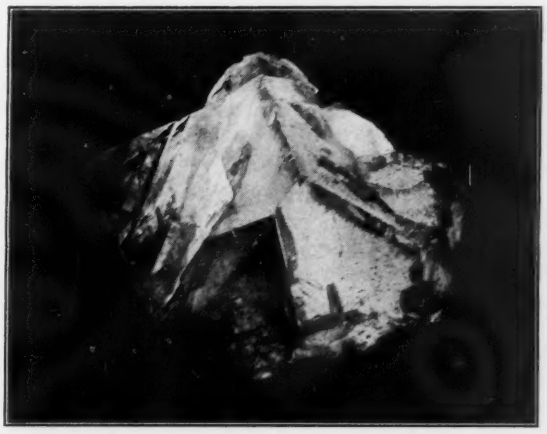

FIGURE 2.—FLUORITE CRYSTAL BY TRANSMITTED LIGHT. THE FACES OF THE CUBE ARE EIGHT INCHES WIDE

$CaCO_3$, preserving the texture of the original limestone, but where crystals are found to have grown out into cavities, an explanation must be given to account for the evident migration of the calcium. It seems reasonable that the solutions contained carbonic acid from the release of CO_2 as indicated above, which dissolved limestone, and calcium bicarbonate coming in contact with fluoride ions at some distance from the limestone would account for the growth of the crystals.

$$H_2CO_3 + CaCO_3 \longrightarrow Ca(HCO_3)_2$$

$$Ca(HCO_3)_2 + 2F^- \longrightarrow CaF_2 + 2HCO_3^-$$

USE AS A METALLURGICAL FLUX

It will be readily understood that the limitations of a brief paper such as this will not permit a discussion of all the uses of fluorspar. Hatmaker and Davis (*6*) have written an excellent statistical review of the fluorspar industry, to which the reader is referred for further details.

The largest consumption of fluorspar is in metallurgy as a flux and depends upon its almost unique property of decreasing the viscosity of slags when added to them, principally in making steel by the basic open hearth (Siemens) process. Briefly, in this process certain of the constituents of pig iron, chiefly C, Si, P, and S, are removed by oxidation, the agent being iron ore. The latter is dissolved in a basic silicate slag which floats on the bath of molten metal. The reactions occur at the slag-metal interface toward which the reactants move by diffusion and convection, the oxidation products dissolving in the slag or escaping as gas. Heat must also be transferred to the metal by the slag, convection being much more effective than conduction

alone. It is evident that the control of the refining process depends to a considerable extent upon the fluidity of the slag. Fluorspar is added when the slag becomes too viscous, the condition being thus promptly corrected.

Smaller amounts of fluorspar are used for similar purposes in electric furnaces making alloy steels and ferro-alloys; in cupola furnaces melting iron; and, to a lesser extent, in the smelting of nickel, refractory ores of copper, gold, silver, and various rare metals.

EFFECT OF FLUORSPAR ON THE VISCOSITY OF BASIC SLAGS

Several years ago the writer conducted an investigation of the effect of fluorspar on the viscosity of basic slags (*7*, *8*), since little was quantitatively known about this important question. The absolute viscosities of molten fluorspar and various slags with and without varying additions of fluorspar were determined through the range of steel-making temperatures, that is, up to 1650° or 1700°C. The viscosity of molten fluorspar, having the composition SiO_2 0.05 per cent., CaO 1.20 per cent., and CaF_2 98.75 per cent. is shown in Figure 4. The sharp break in the curve at 1420°C. and the fluidity at higher temperatures are striking when compared with that of the slags whose viscosities were measured.

In Figures 5 and 6 the viscosity curves of four typical slags are plotted in two ways. Slag Number 1 contained no fluorspar and the additions to Slags Numbers 2, 3, and 4 increased in that order in equal increments. The curves in Figure 5 show almost equal displacements to the left for each increment in the amount of fluorspar added.

The investigation led to the following conclusions:

"(1) Regarding the viscosity of a basic slag, the effect of adding fluorspar is analogous to increasing the temperature.

"(*a*) For a particular molten slag, the lower its temperature the more pronounced is the effect of a given fluorspar addition.

"(*b*) At a given temperature the effect of fluorspar is a direct function of the amount added.

"(2) The decrease in viscosity of a slag caused by the addition of fluorspar is not a temporary effect, but lasts an hour or two at least, provided no other materials enter the slag to change its composition meanwhile.

"(3) The presence of silica in fluorspar, within the limits investigated, does not lower the efficiency of the calcium fluoride, per unit added, in decreasing the viscosity of the slag."

The effect of fluorspar was discussed from purely theoretical considerations and three possibilities were recognized. *First*, the fluidity conferred on slags by fluorspar may be an additive one. *Second*, since a liquid having a structure may be expected to have a high viscosity, fluorspar may inhibit the formation of molecular aggregates, or (*third*) by lowering the freezing point it may displace their formation to a lower temperature.

USE OF FLUORSPAR IN THE PRODUCTION OF HYDROFLUORIC ACID

The production of hydrofluoric acid accounts for the second largest consumption of fluorspar, which is the chief economic source of fluorine. Finely ground fluorspar is mixed with sulfuric acid in iron retorts, the following reaction taking place:

$$CaF_2 + H_2SO_4 \longrightarrow H_2F_2 + CaSO_4$$

The trade requires that the fluorspar be of very high purity, at least ninety-eight per cent. CaF_2 with not more than one percent. of either SiO_2 or $CaCO_3$, for the reason that silica wastes both fluorine and sulfuric acid by forming hydrofluosilicic acid, and calcium carbonate neutralizes the acid and causes foaming in the retort. The volatile hydrogen fluoride passes out of the retort and is collected by one of two methods, depending upon whether aqueous or anhydrous acid is required. The aqueous acid is collected in lead cooling and absorbing towers. It is shipped in lead carboys or rubber-lined barrels, although for laboratory use it is packed in wax

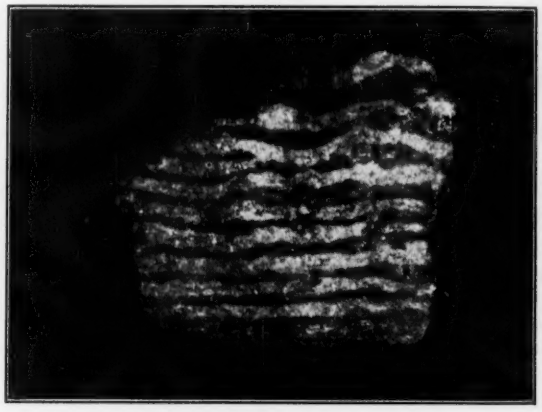

FIGURE 3.—HIGH-GRADE BANDED ORE. THE SPECIMEN IS SIX BY SEVEN INCHES

bottles. The anhydrous acid is condensed by refrigeration and is shipped in containers made of iron, although copper, brass, and even magnesium are unattacked.

Hydrofluoric acid is used in the chemical industry for the synthesis of all fluorine compounds. Limited space permits the mention of only some of the more important ones. For further details the reader is referred to a paper by Reed and Finger (*9*).

ORGANIC FLUORINE COMPOUNDS

The organic fluorine compounds are stable and possess many unique properties. For example, some new refrigerants of suitable thermodynamic properties, containing both chlorine and fluorine, are finding widespread use because they are nonexplosive, nonflammable, noncorrosive, and nontoxic. They are known as Freon or Carrene, the two compounds usually referred

to by these terms being dichlordifluormethane (CCl_2F_2) and trichlormonofluormethane (CCl_3F), respectively. Other Freons are also chlorine and fluorine derivatives of methane or ethane.

INORGANIC FLUORIDES

The salts of hydrofluoric acid find many uses industrially. The alkali, ammonium, aluminum, and zinc fluorides are used as preservatives or insecticides, and zinc fluoride is also used as a wood preservative. Antimony and boron fluorides are used in the synthesis of organic fluorine compounds, the former in the manufacture of Freon and the latter as a polymerizing agent. The alkali and ammonium acid fluorides are used as antiseptics and laundry sours and in the etching of glass. The fluorides of zinc, barium, sodium, magnesium, and aluminum are useful glass and enamel opacifiers. The silico-fluorides are used in electrolytic lead refining (Betts process), the sodium, calcium, and aluminum salts in ceramics, and the zinc, magnesium, and aluminum salts to harden concrete. A great number of other inorganic fluorides are useful in many ways.

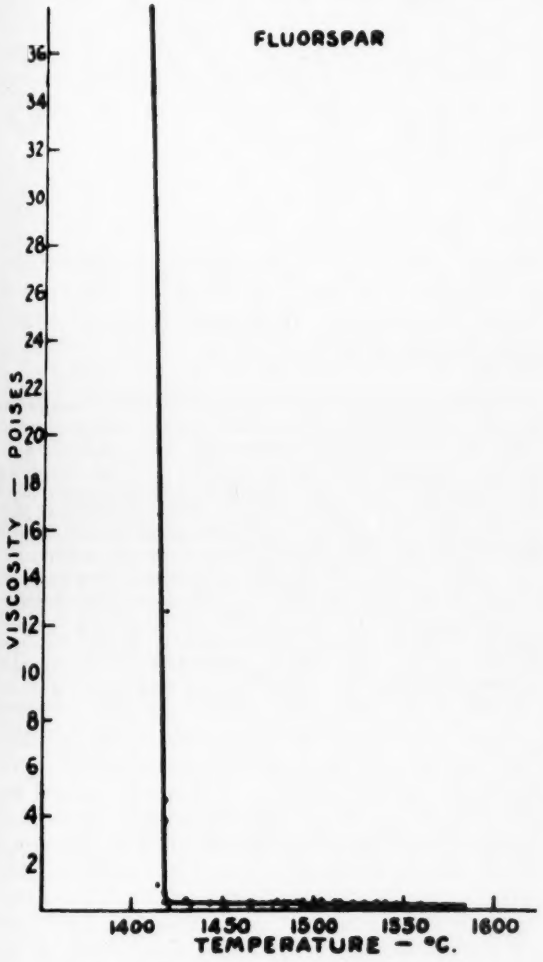

FIGURE 4.—VISCOSITY OF FLUORSPAR

The aluminum industry accounts for a large portion of the fluorspar which is converted into hydrofluoric acid. Synthetic cryolite, $3NaF{\cdot}AlF_3$, is produced from it and used to replace in part the natural mineral in the molten bath from which aluminum is produced electrolytically. Cryolite is found in commercial quantities in only one place in the world, Ivigtut, Greenland, and while it is imported into the United States in considerable quantities, the synthetic material is successfully competing with it.

CERAMICS

Another large use of high-grade fluorspar is in the field of ceramics, in the manufacture of opal glass and enamels. The fluorspar for this purpose must be finely ground, and contain ninety-five per cent. or more CaF_2, with iron, lead, zinc, and sulfur restricted to very small amounts, as they affect the color.

Opal glass is molded into a great variety of shapes with which we come in daily contact. The most common are lamp shades, containers for toilet preparations, rods for towel racks, liners for fruit jar caps, and table, soda fountain, and counter tops.

The enamels on sheet steel and cast iron usually contain fluorspar, added as a flux and opacifier. Articles so enameled include plumbing fixtures such as bath tubs, wash basins, and kitchen sinks, refrigerator linings, cooking stoves, table and counter tops, and signs. The glaze on pottery, tile, and earthen ware might also be mentioned.

OPTICAL FLUORITE

A limited but extremely important use of fluorite is in apochromatic objectives for microscopes. Fluorite has a very low index of refraction, $N_D = 1.4339$, which is lower than that of any other material available for lenses. For this purpose clear, flawless portions of crystals are required, which, due to their scarcity, command high prices. The fluorite apochromatic objectives are superior, *first*, because they have less chromatic aberration. Three optically significant colors may be brought to a focus, whereas with crown and flint glass pairs only two differently colored rays can be so united, and *second*, because they have improved resolving power, due to higher numerical aperture.

For most of the uses to which fluorspar is put, no satisfactory substitutes have been found.

ANALYSIS OF FLUORSPAR: A NEW RAPID METHOD

The old and well-known procedures for the analysis of fluorspar are either inaccurate or long and tedious. Probably the best precise method for the complete analysis of the ore has been developed by Lundell and Hoffman (*10*).

The work of Schrenk and Ode (*11*) on the determination of silica in the presence of fluorite suggests a new and more rapid method for carbonates, calcium fluoride,

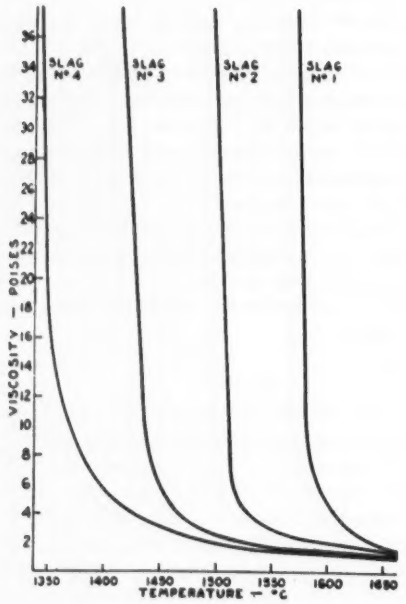

FIGURE 5

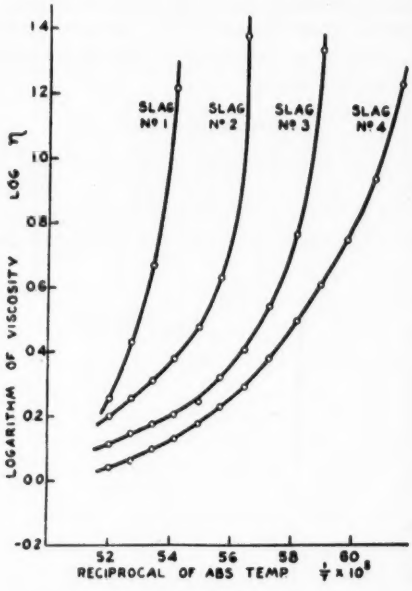

FIGURE 6

EFFECT OF FLUORSPAR ON THE VISCOSITY OF SLAGS

and silica in ores containing no sulfides. In the presence of boric acid, CaF_2 may be decomposed by acids without the SiO_2 being attacked, the reason being that the liberated H_2F_2 immediately reacts with the boric acid to form boron trifluoride. Therefore, the reaction may be carried out in glass beakers, without danger of etching. The acid favored for the decomposition is perchloric, because calcium perchlorate is very soluble and easily removed from the residue. The CaF_2 is completely decomposed and when tested on synthetic mixtures and U. S. B. S. sample of fluorspar Number 79, the method was found to be precise and rapid.

The distinction between $CaCO_3$ and $MgCO_3$ in fluorspar is ordinarily of no significance.

The procedure suggested by the present writer based on the above considerations, is as follows:

1. Digest 0.5-g. sample (finely ground) with ten cc. of ten per cent. acetic acid in a glass beaker on the water bath for one and one-half hours. Filter through ashless paper, wash residue and paper three times with hot water, ignite, and weigh. Report loss of weight as carbonates.

2. Add to the residue in a glass beaker fifteen cc. of twenty per cent. perchloric acid saturated with boric acid at 50°C. Heat gently until fumes of perchloric acid come off for four or five minutes. Add a few cc. of water and repeat the fuming for four or five minutes. Dilute to fifty to seventy-five cc. and after heating the solution, filter through ashless paper. Wash first with a dilute solution of perchloric acid and then with hot water until free of calcium perchlorate. Transfer the residue in the filter paper to a tared platinum crucible, add two drops concentrated H_2SO_4, and ignite. Weigh and report loss of weight as CaF_2.

3. Add five cc. hydrofluoric acid and take to dryness on a sand bath in the hood. If the silica was high, as would be apparent from inspection of the previous residue, this treatment should be repeated to insure complete decomposition. Add a few drops H_2SO_4, to convert Ba to sulfate. Ignite to bright redness, cool in a desiccator, and weigh. Report loss of weight as SiO_2.

4. The residue may contain aluminum and iron oxides and $BaSO_4$, which may be determined by usual methods, if required.

In case the above method is used as a control in production when quick results are necessary and as frequently is the case, knowledge of the silica content is of as much significance as of the calcium fluoride, Steps 2 and 3 may be exchanged, so that the silica is determined before the calcium fluoride, and the latter may be estimated by difference, provided the silica is free and not in solid solution in the fluoride, which would partly protect the silica from attack by hydrofluoric acid.

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TEXAS CHEMICAL LABORATORIES—THEN *and* NOW[1]

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BEFORE the Civil War there seem to have been in all the United States, west of the Mississippi River, only fourteen recognized chemical laboratories (*1*). Three of these were in Texas. The Educational Directory for 1937 lists in this one state alone twenty-four universities and senior colleges and thirty-seven junior colleges (*2*). Probably all of these include chemistry in the curriculum. In view of this contrast it should be interesting at this first national meeting of the American Chemical Society on Texas soil to compare briefly the situation then and now.

St. Louis University seems to have been the oldest of all these educational institutions and the first to teach chemistry. The earliest date given for instruction in chemistry is 1827, actual instruction in other subjects beginning in 1818, the year this institution was founded. Professor J. P. Coony, after a study of old catalogs, thinks 1831 was the earliest date.

In 1829 chemistry was first taught at Centenary College of Louisiana, which has been at Shreveport since 1908. At the time of its founding in 1825 the college was at Jackson, just east of the Mississippi River. In the University of Missouri founded in 1839 chemistry was first taught either in 1842 or 1840.

From a catalog of Ruterville College issued in 1841 it appears that chemistry was first taught in Texas at Ruterville in 1841 by the Rev. C. W. Thomas, A.B. The college had been founded the previous year. This was only five years after Texas became a republic and four years before it was a part of the United States. This institution became Wesleyan College in 1844, McKenzie College in 1848, Soule University in 1856, and finally Southwestern University at Georgetown in 1872. Johnston's revision of Turner's "Chemistry" was the text first used (*3*).

Baylor University was founded February 1, 1845, actual instruction beginning at Independence on May 8, 1846. Chemistry was first taught in 1851 by the Reverend J. B. Stiteler, A.M., who gave lectures to the students in connection with the regular recitation. Johnston's revision of Turner's text was used. Miss Harriett Davis taught chemistry in the "Female Division" in 1851 (*4*). Baylor University has been at Waco since 1868.

In 1853 three western institutions are reported to have begun the teaching of chemistry in the regular college work: Iowa College at Grinnell, Tulane University of Louisiana, and Austin College at Sherman, Texas (*5*). In the Medical School at Tulane chemistry was taught as early as 1834. It is possible that instruction at Iowa College was begun in 1850. Austin College was founded in 1849, and actual instruction began the next year. This may have included chemistry, since it is listed in the curriculum in the catalog published in 1853. In regard to apparatus this catalog states (*6*):

> By the liberality of a distinguished gentleman in New York, the college is now in possession of a splendid Chemical and Philosophical apparatus. This enables the professor, who fills the chair of mathematics and Natural science, to exhibit before his class, experiments and demonstrations highly interesting and instructive.

The earliest record of a text is in 1857, when it is stated that Turner's Chemistry was used. This probably refers to Johnston's revision of Turner's text and it is interesting that all three of the early Texas institutions used the same text.

It is surely noteworthy that of the first eight chemical laboratories west of the Mississsippi River in institutions still in existence, three of them were in Texas. That this interest in chemistry continues today is evidenced by the twenty-three reports, a summary of which is given (see Table 1). These came from all but one of the universities and senior colleges listed in the Educational Directory as Texas institutions, showing a high percentage of promptness, efficiency, and courtesy. To those furnishing this information, whose names are given in Table 1, the gratitude and appreciation of the author are expressed.

These reports show six buildings for instruction in chemistry, all built within the last twenty-one years. Besides, there are a dozen or more science buildings. Most of these institutions maintain a chemical library or reading room. The totals are impressive, not only for Texans, who usually seem quite conscious of the greatness of their great state, but for all chemists. A chemical faculty well over one hundred, nearly twelve thousand students, approximately four hundred thousand square feet of floor space (more than eight acres) with equipment and buildings expressed in millions of

[1] Presented before the Division of Chemical Education at the ninety-fifth meeting of the A. C. S., Dallas, Texas, April 19, 1938.

TABLE 1

TEXAS CHEMICAL LABORATORIES IN INSTITUTIONS OF HIGHER LEARNING—1938

Ref. no.	Name of institution	First instruction	Chemistry first taught	Building for science	Building for chemistry	Date built	Space for chemistry—square feet	Value of equipment in dollars	Chemical library or reading room	Bound volumes	Journals taken	Number of faculty	Number of assistants	Semester hours of chemistry and chemical engineering offered	Students in chemistry	Information given by	Position
(1)	Abilene Christian College	1906	1908		Yes	1929	1,800	6,000	No			1	4	31	82	Jas. F. Cox	President
(2)	A & M College of Texas	1876	1876		Yes	1933	61,120	108,932†	Yes	1,025		31			2,680	C. C. Hedges	Head
(3)	AUSTIN COLLEGE*	1849	1849	Yes		1913	6,000	5,000		400	4	2	3	34	45	P. S. Wharton	Professor
(4)	BAYLOR UNIVERSITY*	1846	1851	Yes		1901	7,800	20,000		525	8	2	14	60	300	W. T. Gooch	Professor
(5)	Daniel Baker College	1889	1889	Yes		1870	3,000	6,295	Yes	35	2	1	3	26	20	Mrs. T. E. Ward	Head
(6)	Hardin - Simmons University	1892	1892	Yes		1919	8,500	14,500	Yes	1,676	7	2	4	60	155	H. R. Arrant	Professor
(7)	Howard Payne College	1890	1900	Yes		1934	1,500	3,000	No	0	0	1	6	36	70	O. E. Winebrenner	Professor
(8)	Incarnate Word College	1909	1909	Yes		1926	5,432	10,000		367	9	2	3	40	130	Sister M. E. O'Byrne	Chairman
(9)	MARY HARDIN-BAYLOR COLLEGE*	1846	1851	No	No		4,800	4,000	No	500	5	2		42	100	Amy LeVesconte	Professor
(10)	McMurry College	1923		No	No		800	1,000	No		2	1	4	32	100	Harold G. Burman	Professor
(11)	Our Lady of the Lake College	1911	1911	Yes		1937	11,168	12,650	Yes	523	8	3	0	42	54	Sister M. Clarence	Professor
(12)	The Rice Institute	1912	1912		Yes	1924	65,000	70,000	Yes	9,000	40	7	14	132	800	Harry B. Weiser	Professor
(13)	St. Edward's University				No data									No data			
(14)	St. Mary's University of San Antonio	1852	1884		Yes	1918	4,600	13,000	Yes	875	7	4	0	33	140	Edw. Collignon, S.M.	Head
										831	11	3	6	44	340	E. D. Heuse	Head
(15)	Southern Methodist University	1915	1915		No		5,000	12,000	Yes	2,000	6	2	4	66	115	J. C. Godbey	Head
(16)	SOUTHWESTERN UNIVERSITY*	1840	1841	Yes		1917	6,730	10,000		700	12	2	10	63	140	J. L. Whitman	Head
(17)	Texas Christian University	1873	1873	No	No		4,500	15,000	Yes	300	4	2	5	53	286	John L. Nierman	Head
(18)	Texas College of Arts and Industries	1925	1925	Yes		1938	9,054	6,000	No	1,900	21	8	8	47	591	W. H. Clark	Director
(19)	Texas State College for Women	1901	1901	Yes		1936	6,600	38,000	Yes	1,000	15	8	24	96	1,256	W. M. Craig	Professor
(20)	Texas Technological College	1925	1925	Yes		1929	25,000	21,000	Yes	17	2	1	4	27	80	A. M. Ewing	Professor
(21)	Texas Wesleyan College	1892	1892	No	No		3,400	2,000	Yes	338	5	1	3	46	69	J. B. Ford	Head
(22)	Trinity University	1869	1891	No	No		3,700	10,655	No	100	6	2	3	42	170	G. V. W. Drake	Professor
(23)	The University of Houston	1927	1927	No	No		6,000	15,000	Yes	10,000	90	31	25	334	3,471	H. R. Henze	Head
(24)	The University of Texas	1883	1883		Yes	1930	125,200	75,443		522	8	3	5	22	220	F. H. Seamon	Professor
	College of Mines and Metallurgy—branch of University of Texas	1914	1914		Yes	1917	6,700	18,000†									
							383,404	497,475		32,634		122			11,414		

* Institutions founded before the Civil War.
† Includes desks and office furniture.

dollars—these are definite and tangible evidences of the present interest of Texas in chemical instruction and research. The Department of Chemistry at the University of Texas is probably the largest south of the Mason and Dixon line, especially in graduate work.

Approximately two-thirds of the student enrolment of chemical students is in state-supported institutions. It should be remembered that our totals do not include the eight professional schools, nor the seven teachers colleges, thirty-seven junior colleges, and thirteen negro colleges listed in Texas in the Educational Directory of last year (*2*).

It is doubtful if there were any commercial or industrial laboratories until some years after the Civil War, but these are also numerous now. A list kindly furnished by Mr. R. H. Fash, vice-president of The Fort Worth Laboratories, is given (*7*). (See Table 2.)

TABLE 2

TEXAS COMMERCIAL AND INDUSTRIAL LABORATORIES—1938

The Fort Worth Laboratories, Fort Worth, Texas	1912
Southwestern Laboratories, Dallas, Texas	1917
Southwestern Laboratories, Houston, Texas	1926
Southwestern Laboratories, San Antonio, Texas	1927
Houston Laboratories, Houston, Texas	about 1905
Galveston Laboratories, Galveston, Texas (Dr. Felix Paquin)	Date not known
Landon C. Moore, Dallas, Texas	probably 1906
Texas Testing Laboratories, Dallas, Texas	1926
Dallas Laboratories, Dallas, Texas (Dr. Rosenthal)	Date not known
Industrial Laboratories, Fort Worth Texas (Harry M. Bulbrook)	1927

The three Texas chemical laboratories before the Civil War are noteworthy and indicate the early interest in chemistry; the many laboratories with modern equipment, thoroughly trained faculties and large numbers of students now are not only significant, but furnish a firm basis for the great and growing industries of the state.

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A MODEL *of a* MODERN SEWAGE TREATMENT PLANT *as a* PROJECT *in* HIGH-SCHOOL CHEMISTRY

WILLIAM MAYROSE

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A display model of a sewage treatment plant was constructed by a group of eight high-school boys. The greater part was made of wood, on a scale such that one-fourth of an inch on the model equaled twelve inches on the actual plant. The blueprints used in constructing the plant were used for details on the model. All important parts were represented in their relative positions, a number of the smaller details also being shown. The entire model was labeled, the course of the sewage through the plant being indicated by numbers.

✦ ✦ ✦ ✦ ✦ ✦

THIS project was undertaken partly because a model along similar lines of the water filtration plant of this city had previously been built[1] and because of a desire on the part of the writer to have the two models for use in teaching that part of the course in chemistry on water purification and sanitation.

A set of plans used in the construction of the treatment plant were obtained from the superintendent of the plant. These were used in building the model, the scale being reduced such that one-fourth inch on the model was equal to one foot on the actual plant.

A trip was made to the treatment plant, by the students who had volunteered to build the model, where the details of construction and operation were explained by the superintendent. The students then met to study the blueprints and to formulate plans for building the model. The work very conveniently fell into three distinct parts; the main control house and the grit chamber, the clarifiers with their troughs and scraping mechanisms, and the digesters with their control house (Figure 1). The students who had volunteered then selected parts that they desired to construct. One boy had a workshop in the basement of his home where he built the main control house and the grit chamber. The other work was done in the chemistry rooms which were equipped with a work bench and a few tools. One boy was in a course in cabinet-making and had access to the machinery and tools of that department.

The main control house is a small brick building containing the office, chlorination apparatus, sludge filters, chemical laboratory, pumps, and so forth. In the model this was constructed of one-fourth inch white pine. The partitions were installed in such manner that the arrangement of the rooms and corridors were accurately shown. Windows were made of clear isinglass. There was only a single story and basement, these being made in separate parts so that they could be taken apart and cleaned. The floor was made of a piece of ordinary window glass so that the labels and descriptions placed on placards in the various rooms could be read. A piece of window glass was placed over the top of this building and fastened in place by a strip of molding. This building is nine and one-half inches by twelve inches by six inches.

[1] MAYROSE, "A model of a modern water filtration plant as a project in high-school chemistry," J. CHEM. EDUC., **16**, 239 (1939).

All sewage entering the treatment plant flows into the grit chamber, a tank twenty feet square and about four feet deep. Sewage passes through this tank at a rate of about one foot per second. At this rate the very heavy solids settle to the bottom and are removed by a scraping mechanism. This is a large three-blade scraper that is turned by an electric motor, such that the settled solids are scraped to one side of the tank and removed by being scraped up an incline and discharged into a pit at the side of the tank. This scraper mechanism was made of wood, the three blades being made of a piece of white pine onto which were glued small pieces of balsam sloping toward the floor. These blades resemble somewhat the backbone of a fish. This mechanism is guided around the grit chamber by a railroad track on top of the wall of the chamber. A piece of one-eighth inch track was obtained from a supply house furnishing materials for models. The wheel that runs on the track was carved out of a piece of lead.

The sewage from the grit chamber containing the more finely divided solids in suspension passes into the clarifiers. There are two clarifiers, each one hundred thirty-six feet long, thirty feet wide, and ten feet deep. The velocity of the sewage in these tanks is retarded sufficiently to allow the suspended matter to separate from the liquids. The heavier solids settle to the bottom and are called raw sludge, while the lighter solids such as grease, oil, matches, and so forth, rise to the surface and are called scum. To collect these solids each clarifier has three sets of collectors; two designated as longitudinal and one as a cross collector. The longitudinal collector consists of two endless chains running nearly the complete length of the clarifiers. To these are attached as scrapers pieces of redwood two inches by six inches. The whole mechanism resembles a huge ladder, the cross pieces being the scrapers and being spaced about six feet apart, the sides being the two chains. This scraper mechanism moves about three feet per minute over sprockets that are driven by electric motors. It is guided along the sides of the clarifiers by steel guide rails.

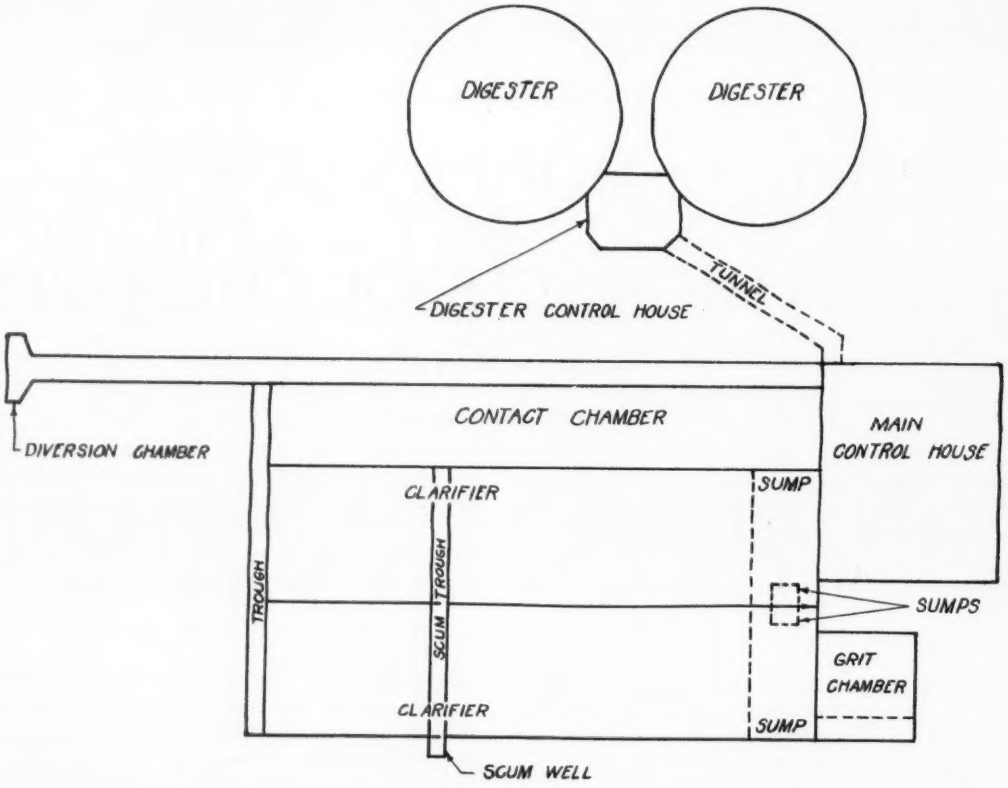


FIGURE 1.—GENERAL LAYOUT OF THE TREATMENT PLANT

The clarifiers, contact chamber, and diversion chamber were constructed as a single box, twenty-one inches wide, thirty-four inches long, and two and one-half inches deep, with partitions setting off each of these sections. Ordinary furnace chain was used to represent the chain in the collectors, various links being spread apart and pieces of soft iron, one-eighth inch square and three inches long to represent the scrapers were slipped into these links which were then

squeezed together holding the iron in place. The guide rails were made by tacking thin strips of wood to the walls of the clarifiers. A number of different types of sprockets were considered. One boy suggested alarm clock wheels; another thought they might be made by cutting lead washers. Finally three-fourth-inch brass washers were used, the teeth being cut on them at the school machine shop. The shafts on which the sprockets are fastened were represented by three-eighth-inch doweling, these being nailed and glued to pillars supporting the cross walks on top of the clarifiers.

The scrapers while on top of the clarifiers are about half submerged in the sewage and in this position are enabled to carry the scum to the scum trough. This trough extends over the entire width of the two clarifiers and in the model was made of a piece of grooved

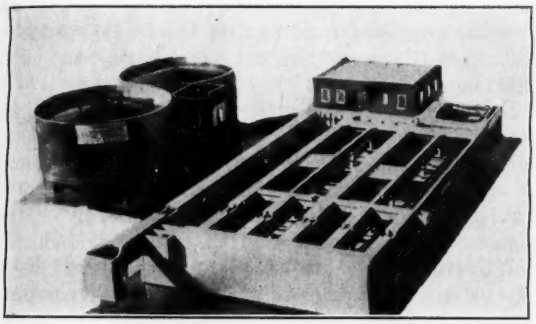


FIGURE 2.—THE COMPLETED MODEL

wood. The scum flows from this trough to the scum well, represented in the model by a small box fastened to the side of the clarifier. From here the scum is pumped to the digesters.

This scraping mechanism passes under the scum trough and to the far end of the clarifier several feet under the sewage. Here they pass over a pair of sprockets that guide them to the bottom of the tank. On the bottom they scrape the raw sludge to the opposite end of the clarifier where it is discharged into a cross collector sump. This occupies about seven feet of one end of the clarifiers and has a floor about three and one-half feet lower than the other portion of these tanks. It has a cross collection mechanism, similar to, but smaller than, the transverse collector and operates at right angles to the direction of flow of sewage in the clarifier. This cross collection mechanism scrapes the raw sludge into a smaller sump from where it is removed by suction and transferred to the digesters.

On the model these sumps were made separate from the other portion of the tanks by cutting a piece of two by four, then installing it in the proper place. The cross collection mechanism was made the same as the longer collector except, of course, smaller. The sprockets and shafts were made in the same manner.

On top of the partition separating the clarifiers and contact chamber are concrete walks, represented in the model by strips of wood painted light gray to resemble the concrete. In the actual plant, that section of the clarifiers beyond the scum trough has a series of troughs, covered with iron grating. In the model these troughs were covered with strips of wood, cut away so that an observer might see below.

Sewage from the clarifiers flows through weirs into these troughs and then to the contact chamber. This

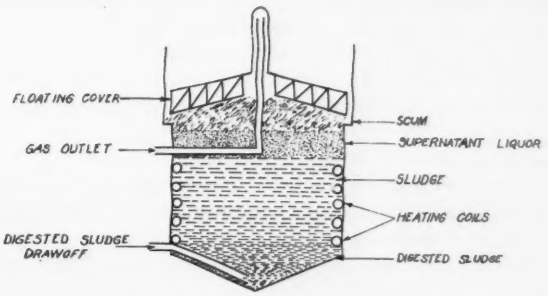


FIGURE 3.—CROSS-SECTION OF A DIGESTER SHOWING THE LAYERS OF THE CONTENTS

is a tank about one hundred thirty-six feet long, sixteen feet wide, and ten feet deep. Its purpose is to allow the chlorine, when added, to remain in contact with the sewage long enough to kill the bacteria present in the clarified sewage.

On the outer wall of this chamber are two conduits, one above the other. Each is three feet wide, the lower one being two and one-half feet deep, while the upper one is five feet deep. Sewage from the clarifiers flows through this lower conduit to the contact chamber. Chlorine as chlorine water is added about midway in this conduit. A set of baffles directs the flow into the contact chamber. The sewage leaves the contact chamber flowing through side weirs, into the upper conduit, and out to the river through the diversion chamber.

These conduits were installed and a portion of the outside wall cut away so that the construction details could be seen. The side weirs in the contact chamber can be easily seen in Figure 2.

The sludge from the clarifiers is pumped to the primary digester. There are two digesters, the other being called the secondary. The primary digester has twice as many hot-water heating coils as the other, since the raw sludge that is added is cold and must be heated in this tank to a temperature where bacterial action will take place. These digesters are concrete tanks, fifty-five feet in diameter, and twenty-five and one-half feet deep. Each has a steel cover which floats on the contents, rising and falling as additions and withdrawals are made. In these digesters bac-

terial action destroys a portion of the organic matter, changing a portion of the raw sludge to a non-offensive digested sludge. During this action a large quantity of gas, high in methane, is produced. This gas is collected and used about the plant for heating purposes, the excess being burned in a specially constructed burner outside.[2]

The contents of these digesters tend to separate into three distinct layers (Figure 3). These consist of lighter solids that are carried up with the gas, tend to stay on top, and form a scum layer. Just below this is a layer of material mostly liquid, and from this to the bottom the amount of solids increase. This bottom layer is called sludge. As the bacterial action continues, the sludge becomes more digested, and its specific gravity increases, the more completely digested sludge settling to the bottom. In the primary digester, these layers are not as pronounced as in the secondary because of the large amount of gas that is given off, keeping the contents fairly well mixed.

The partially digested sludge is transferred from the primary to the secondary digester, the transfer being made ordinarily once each day. Raw sludge is pumped into the primary digester, usually three times per day.

In the model these tanks are fourteen inches in diameter and six and one-half inches high. They were mounted on blocks of wood to bring them to the proper elevation. The base was made of a thick piece of wood to which was nailed and glued thin strips for the sides. The top was made of a piece of five-ply veneer to which was fastened a piece of galvanized iron in the shape of a cone with a diameter of fourteen inches and altitude of three inches. Two sampling wells were made of one-eighth-inch copper tubing which was soldered in place. A manhole was made by soldering a portion of a bouillon cube can to the cover, while a small tin can was soldered in place to represent the trap in which the gas is collected. A gas-pipe housing, permitting the cover to move up and down over the gas outlet pipe was made from an old Bunsen burner barrel, plugged on one end with putty.

Inside the digesters the heating coils were made of heavy copper wire. A piece of one-eighth-inch cast iron pipe was installed as the digested sludge draw-off pipe. In order that these parts inside could be seen a section of the roof was cut away.

The digester control house containing valves and pipes for controlling the flow of material from one digester to the other is included in the model although not many of the pipes and valves were shown. One set, however, was made of one-fourth inch doweling. These represented a set of pipes and valves from which samples of sludge could be drawn at various levels from the digesters, the purpose of these samples being to determine at which level sludge should be taken from the digesters.

The digested sludge is carried from the secondary digester to the basement of the main control house through a pipe in a tunnel. The tunnel was included in the model, galvanized iron wire being used for the pipe. This tunnel also contains pipes for carrying the raw sludge to the digesters, the hot water with cold water return, the gas from the digesters, and the supernatant liquid from the digesters. A portion of the top of the tunnel was cut away so that the inside could be seen.

From the sludge well, the sludge is lifted by bucket elevators to the vacuum sludge filter. This filter consists of a pair of drums covered with canton flannel. A vacuum inside causes the liquids to be forced in, leaving the dry sludge on the outside. Before the digested sludge is placed on the filter, ferric chloride and hydrated lime are added to coagulate the finely divided solids, making the filtration more complete. This sludge cake is sold, being used as top dressing for lawns. The sludge well and filter were not included in the model.

Labels were placed at various points throughout the model describing the size and function of that part of the actual plant.

In addition to the model a description of the entire sewage system of the city has been prepared and is used in the chemistry course. To accompany this description a number of photographs have been taken, showing different parts of the plant. Some of these show similarities between model and corresponding parts of the actual plant while others show views of the plant not included in the model. This has served as a very effective means of presenting this phase of the course.

[2] At present there are about 40,000 cubic feet of gas being produced per month.

INCREASE REPORTED IN JUNIOR COLLEGE ENROLMENT

Enrolment in junior colleges in the United States has doubled in the last seven years, according to the 1940 Junior College Directory, just issued by the American Association of Junior Colleges. Enrolment has increased from 155,588 to 196,510 in the last year. This 40,922 increase, which is 26.4 per cent., is the greatest ever reported, according to Walter C. Eells, secretary of the Association. There are now five hundred seventy-five junior colleges, as compared with five hundred fifty-six reported a year ago.

The NEW SARTORIUS-RAMBERG MICRO-BALANCE[1]

JULIUS KUCK AND ERICH LOEWENSTEIN[2]

The City College of the College of the City of New York, New York City

ALTHOUGH the first microchemical balance was built in 1886 by E. Warburg and T. Ihmori (*1*), and other types appeared in the decades following (*2*, *3*, *4*, *5*), it was not until 1910 that F. Emich of Graz adapted the refined assay balance to microchemical work (*6*). This short-beam type of balance possesses many advantages peculiar to this kind of construction, the most important being a lighter beam mass, a greater freedom from deviations caused by unequal expansion of the lever arms, less flection of the beam, and a shorter period of oscillation.

F. Pregl quickly recognized these advantages of the assay balance, but he realized that certain improvements would have to be made in order to make it a useful instrument for ordinary laboratory work. Therefore, he commissioned W. H. F. Kuhlmann of Hamburg to construct an improved microchemical balance with the special rider, the reading lens, the screw for the adjustment of the center of gravity, and the hooks for the absorption of filter tubes. This was the famous model Number 19-b (*7*).

In recent years several other firms have put on the market micro-balances embodying the same principles of construction as those of the Kuhlmann balance, but differing slightly in a few features. Kuhlmann has added a few innovations to his balance, the telescopic reading device and the detachable housing, but he has not changed the fundamental principles of his instrument, particularly the form of the rider and the style of the rider-carrying mechanism.

In 1933 Professor Ramberg of the University of Upsala reported his careful study of different riders and the causes of rider error (*8*). At his suggestion the Sartorius Company of Göttingen, Germany, undertook the construction of a special micro-balance equipped with a small two-milligram quartz-stick rider, because Ramberg had proved mathematically that such a rider has the optimum form. Unfortunately, the original report of this balance was in Swedish and did not readily come to the attention of microchemists in the English-speaking countries. Moreover, in spite of the fact that both the theory and design of this balance were sound, the actual workmanship of the first of these micro-balances which appeared in this country was inferior to the artistic craftsmanship of Kuhlmann. The chief trouble with the tiny quartz-stick rider was its tendency to fall from the notch in the balance beam unless it was deposited exactly balanced in its middle by the rider carrier. Since the balance case was of wood and the rider-carrying device was attached to it by means of screws, only a slight warping of the wood sufficed to throw the rods of the rider carrier out of line with the beam and attempts to correct this made matters worse. The thin quartz stick was easily lost and hard to pick up with the forceps when found. Its constant replacement to the balance beam was a source of annoyance to the analyst.

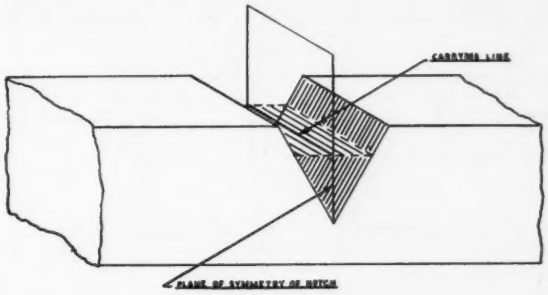


FIGURE 1

To meet this objection the Sartorius Company withdrew its original Ramberg micro-balance from sale on the market and after considerable research by its technical staff is now introducing a new micro-balance with a metal case by which the rider carrier is kept in a more perfect alignment. The new balance is shown in the accompanying illustration and is subsequently described.

THEORY OF THE RAMBERG BALANCE

Because of the theoretical importance of Ramberg's article it has been thought advisable to give a résumé of it in English. The starting point of his consideration is the mathematical statement that for an accuracy of one microgram in a weighing on a microchemical balance, the moment of the rider (force × distance or $r \times l$) must be so reproducibly defined that its error does not exceed the moment of a mass of 0.001 mg. on the right pan; ($r \times l$) must be equal to or

[1] Since this article was submitted for publication the experimental model in question was returned to the Sartorius factory for a few minor changes in design, including the addition of a magnifying lens for the rider-carrying device. Before the outbreak of the war only three of these balances had been received in this country.

Recently an American manufacturer has agreed to attempt the production of a microchemical balance embodying the features described in this article.

[2] Technical Adviser, Pfaltz & Bauer, Inc., 350 Fifth Avenue, New York City.

less than 0.001 $L/2$ where r is the mass of the rider, l its distance from the central knife, and L the total length of the beam between the end knives. He pointed out the concept of an ideal rider which is assumed to be perfect in form and frictionless, the ideal notch which is smooth and symmetrical, and the real rider and notch which are actually met in practice. A rider may be considered to have four contacts which lie in one plane. The intersection of this plane with the rider plane is called the "carrying line." In (Figure 1) the ideal case the carrying line should lie in the plane of symmetry of the notch, but in the real instance it is not sharply defined, since the same rider may have different carrying lines in the same notch depending upon its position in that notch.

Certain errors in microchemical weighing may be grouped into two types: (*A*) those due to errors in the instrument, and (*B*) those due to the faulty rider position, which are termed "dislocation errors." In the former group (*A*) we find: (*a*) The mass of the

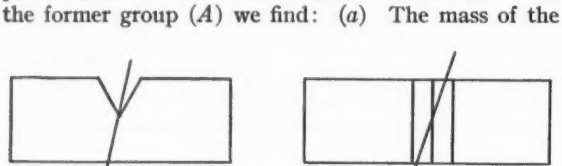


FIGURE 2

rider deviates from its earmarked value (for example, a Kuhlmann rider may not exactly equal 5 mg.). (*b*) There may be divisional errors symbolized by (δl) where the distance of the notch from the vertical plane of the central knife edge is in error. In the fabrication of the instrument the divisions on the rider scale may not be exactly a proportionate distance from the vertical plane of the fulcrum. However this error is not serious because δl is a constant. (*c*) The middle of the notch may not lie in a plane perpendicular to the rider scale and parallel to the central knife edge.

Dislocation errors (*B*) depend upon the form of the rider, the condition of the notch, and various uncontrollable factors. In this category may be included: (*a*) the case where the rider sticks to the side of the notch and does not reach its lowest point—($\delta' l$). Here the carrying line obviously cannot coincide with the plane of symmetry of the notch. (*b*) "Angle errors"—($\Delta\phi$): the rider is not frictionless, and its plane is inclined to a horizontal plane which is perpendicular to the rider scale and which passes through the central knife edge. Its position has two components, since the rider plane may make either a horizontal or a vertical angle with the vertical plane perpendicular to the longitudinal axis of the rider scale (Figure 2). By the geometry of the adjacent diagram, an equation for the moment of the rider (beam horizontal) can be easily deduced (Figure 3).

$$\mu = (l \pm d \cdot \sin\phi) \cdot r \cdot g \qquad (1)$$

where μ = moment in dynes, l = distance in millimeters of the carrying line from the vertical plane of the central knife edge, d = distance in millimeters between the carrying line and the center of gravity of the rider, ϕ = the acute angle between the plane of the rider and the vertical plane of symmetry of the notch, r = the mass of the rider in milligrams, and g = the gravitational force on a mass of one milligram (0.980 dynes).

Dislocation and angle errors are known as "non-reproducible errors" since the moment of the rider in a given notch cannot be reproduced with certainty if the rider is raised from the notch and replaced.

All of the sources of error may be grouped as follows:

Length errors (Δl)	{ Division errors (δl)
	{ Dislocation errors ($\delta' l$)
Angle errors ($\Delta\phi$)	(Non-reproducible errors)

Ramberg deduced the following expression for the length tolerance for an accuracy of ± 1 microgram (T_l) which may be defined as the greatest allowable error in the position of the carrying line.

$$(\Delta\mu) = \frac{0.001 \cdot L}{2} \cdot g \qquad (2)$$

where L = distance between the end knives and when $\phi = 0$ or remains constant. From equations (1) and (2) we get: $(\Delta l) = \dfrac{0.001 \cdot L}{2r}$ where $\Delta l = \delta l + \delta' l$ (algebraic sum).

$$(\Delta l) = \frac{0.001 \cdot L}{2} = (T_l)\gamma \qquad (3)$$

For a Kuhlmann balance where r = 5 mg. and L = 70 mm., (T_l) = 0.007 mm.

This means that the position of the carrying line must be exactly reproducible on the Kuhlmann microbalance to within 0.007 mm. Although the dislocation error may be just within this tolerance limit, there is no latitude for a divisional error in the same direction.

Table 1 gives the length tolerance for some other micro-balances which are in common use.

TABLE 1

Micro-balance	*L in mm.*	*Rider weight in mg.*	*T_l in mm.*
Sartorius	80	5	0.008
Starke and Kammerer	80	5	0.008
Bunge	140	5	0.014
Nemetz	72	5	0.007
Becker	100	5	0.010
Ramberg	80	2	0.020

Ramberg emphasized the fact that angle errors are much more serious than dislocation errors. He derived an equation for the angle tolerance, *i. e.*, the greatest numerically allowable angle error which would permit an accuracy of ± 1 microgram. If we assume that the cos ϕ is just a little less than 1, from Equations (1) and (2) we get:

$$(\Delta\phi) = \underset{\text{radians}}{\frac{0.001L}{2r \cdot d}} \cdot \underset{\text{degrees}}{\frac{360}{2\pi}} = T_\phi \qquad (4)$$

If we estimate 2 mm. as the distance between the carrying line and the center of gravity of the rider, T_ϕ calculates to 0.2° or 12′ in the case of the Kuhlmann 5-mg. rider. This means that if a Kuhlmann rider resting in one notch is raised and then replaced in the same notch or put in some other notch, the difference in the acute angles with the vertical plane for two comparable settings must not exceed 12′ if we wish to attain a reproducible accuracy of ±1 microgram. Another calculation shows that if we assume that a given angle deviation for two different settings amounts to as much as 1° which is still a very small variation, a weighing error of five micrograms is already introduced from this cause alone. Approximately this same condition prevails with all other riders which have an appreciable distance between their centers of gravity and their carrying lines.

In the last few years there has been a tendency on the part of designers of micro-balances to devise riders with lower centers of gravity on the theory that this would make their riders stand more upright. However, equation (4) shows that the angle tolerance varies inversely to d, so that this practice has actually defeated their desire, because the lower the center of gravity of the rider, the greater d is, and therefore a greater demand is made upon the angle tolerance. Furthermore, the equation shows that with any of the current styles of rider it is mathematically impossible to achieve a reproducible accuracy of ±1 microgram.

For this reason Ramberg turned his attention to a type of rider by which angle errors could be lessened if not eliminated. This can be done theoretically either by increasing L in the formula, or by decreasing either r or d or both. It is out of the question to increase L because it is necessary to retain the other more important advantages which short beam balances possess. He, therefore, first investigated the effect of diminishing the rider mass and his results are shown in Table 2 which applies to the Sartorius micro-balance where L = 80 mm., d = 5 mm.

TABLE 2

$2n+1$	n	r	P	T_l	$T\phi$	F
101	50	5	10	0.008	0.092	0.011 mg.
41	20	2	4	0.02	0.23	0.0044
21	10	1	2	0.04	0.46	0.0022
11	5	0.5	1	0.08	0.92	0.0011

$2n+1$ = the number of notches on the rider scale.
r = the mass of the rider (mg.).
P = the largest mass difference (mg.) which can be obtained by shifting the rider from the zero notch to the last notch.
(T_l) = length tolerance in mm. for 1 microgram.
$(T\phi)$ = angle tolerance in degrees for 1 microgram.
F = the weight error (milligrams) resulting from an angle deviation of 1°.

A study of this table shows that one or two milligrams is the best weight for a rider of the metal type since riders of smaller weight are too deformable. There is no practical gain in tolerance by diminishing the rider mass further.

The other alternative for decreasing angle errors is to make the value d smaller. This can be accomplished by a radical change to a different shape of rider. Ramberg suggested a cylindrical form of rider (quartz stick) which rests securely in the notch of the rider scale. If the tiny quartz stick is straight without any bending there is only a very small d. There is also

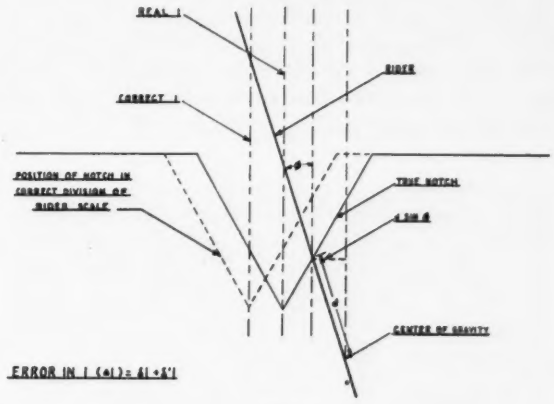


FIGURE 3

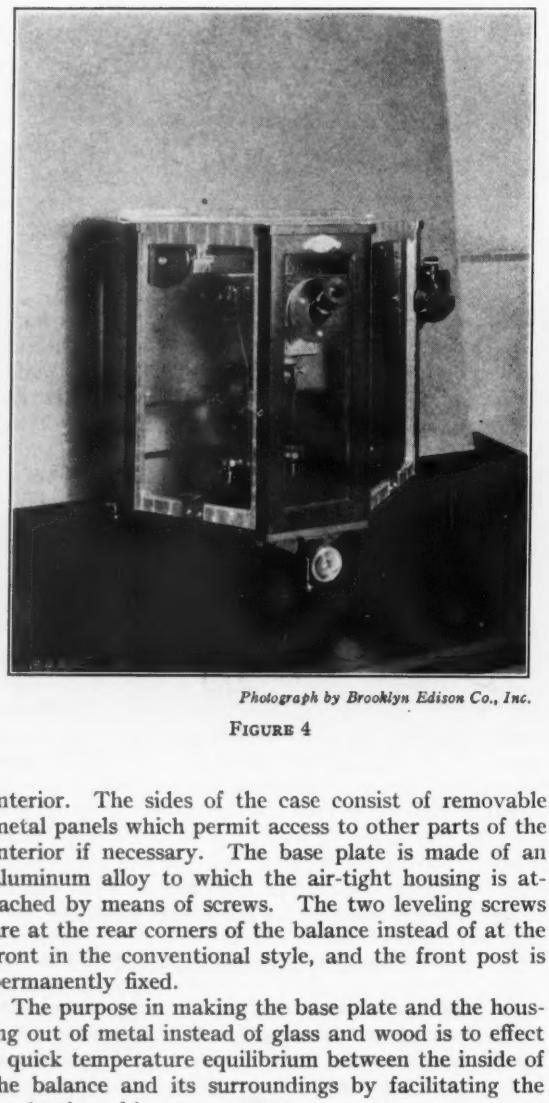
the advantage of reducing frictional effects to a minimum since the rider is less likely to stick to the side of the notch but is free to roll to the lowest point. In order for d to be small, it is also important that the ends of the stick be perpendicular to the axis of the cylinder and that it have a uniform cross-section which is round. It has been found technically possible at the Sartorius factory to make a careful selection of quartz-stick riders which will satisfy these requirements by means of microscopic examination.

It may be said that a precision of 1 μg. is not important in many microchemical weighings; for example, in organic analysis, because objects do not have to be weighed to such an absolute accuracy. It seems desirable, however, that all causes of error from whatever source should be most carefully considered. Among the most likely of these in the case of the equal armed lever balance are those due to faulty rider placement. There is no doubt but that many a well-executed carbon or hydrogen analysis has fallen just short of the analyst's desired goal because the rider positions varied too much in several weighing operations. For this reason a reproducibility of ±1μg. should be the desirable objective in micro-balance design.

TECHNICAL DESCRIPTION

The new Sartorius micro-balance has a metal case which is composed of a special alloy consisting principally of aluminum, copper, and zinc. The case is forty inches wide, twelve inches deep, and fifteen inches high. The total weight of the balance is about seventeen pounds. The front part of the case is shaped like

half of a vertical hexagonal prism, and the back part is a rectangular parallelepiped. The housing is equipped with a large glass window at the rear, and with two vertically sliding window frames with full length glass. There is a stationary glass panel between these two doors through which the reading telescope projects. Instead of the conventional catgut window cord and sash-weights for counterbalancing the doors, this model is equipped with thin steel tapes winding on spools which are provided with springs to furnish the necessary tension. There is also a removable glass panel at the top which permits easy access to the beam from above and to the rider-carrying device. This has the advantage of admitting ample light to the



Photograph by Brooklyn Edison Co., Inc.

FIGURE 4

interior. The sides of the case consist of removable metal panels which permit access to other parts of the interior if necessary. The base plate is made of an aluminum alloy to which the air-tight housing is attached by means of screws. The two leveling screws are at the rear corners of the balance instead of at the front in the conventional style, and the front post is permanently fixed.

The purpose in making the base plate and the housing out of metal instead of glass and wood is to effect a quick temperature equilibrium between the inside of the balance and its surroundings by facilitating the conduction of heat.

The precision-double arrestment is controlled at the front of the balance instead of at one side on the theory that temperature effects from the operator's hands will thereby be eliminated.

The pillar (one hundred fifty millimeters long and fifteen millimeters in diameter) is more rugged than the Kuhlmann center post which is only one hundred millimeters long and ten millimeters in diameter. It is securely fastened to the base plate by three screws.

An optical reading device is fixed to the pillar of the balance. A photomicrographed glass scale is fixed on the pointer and is illuminated by a system of prisms, one of which can be turned toward a near-by light source so that light of maximum intensity can be projected on the scale. An entire support for the optical reading device is rigidly clamped to the center post and carries a spirit level. This level is built directly into the casting in order to show that the central pillar itself is perpendicular in all directions to the horizontal plane regardless of the level of the balance floor. This scale may be read on a hair-line plate, by means of a microscope objective, and thus in this design the hair-line and the scale are observed simultaneously in the eyepiece. The hair-line plate may be shifted by means of a screw in order to make both graduations coincide when the balance is at rest.

When the pointer swings, the illuminated scale moves by the stationary hair-line. Each scale division represents ten micrograms so that thousandths of a milligram may be readily estimated without eyestrain on the part of the analyst. The beam is two millimeters thick as compared with the Kuhlmann beam which is about one millimeter thick. This width is necessary in order to hold the stick rider in its proper place. The Sartorius beam and pointer are much heavier than the Kuhlmann, their weights being, respectively, 41.8 g. and 24.6 g. on the two particular models which were compared.

In the new Sartorius micro-balance, the style of beam which embodies the use of holes to cut down the weight has been replaced by a solid beam form which is similar to the Kuhlmann beam. This is eighty millimeters long which is the optimum value, but with such a light rider the maximum weight which can be determined in the last notch is only four milligrams. Each one of the forty-one notches represents one-tenth of a milligram. The balance is equipped with a fractional weight manipulation to supplement the maximum obtainable weight of four milligrams. This enables the operator to add four- or six-milligram weights on an auxiliary beam without opening the case.

The rider-carrying device of the previous model has proved itself worthy of being retained in the new model, although the rider is a little longer than formerly (*9*). The rider is picked up and set down by two leaves which spread apart when the rider is lowered to the beam and which shut together when the carrier is raised. In this way the stick is exactly centered each time that it is deposited in a notch. Although the carrier is a very ingenious device, it is one which requires high precision

in manufacturing the many necessary small parts. Moreover, the greatest cleanliness of the rider wings has to be maintained at all times to prevent the stick from being drawn off the beam when these wings spread apart. The rider is so light that it may cling to a dirty glass surface. However, this is no reflection upon the manufacturer but rather the obligation of the analyst.

EXPERIMENTAL WORK

An experimental model of the new Sartorius-Ramberg microchemical balance recently arrived at the laboratory of the City College and was in continuous use by students for almost a year. Although it is not fair to test the accuracy of a balance under such conditions, certain routine tests were made. The balance was set upon soft rubber stoppers in a large case which was especially designed for it. This exterior case was also mounted on rubber stoppers which stood upon a solid wooden table. All tests were made at times when the operator could be alone in the laboratory so that there would be no vibration from people walking by. As constant a room temperature as possible was maintained although it was found to change as much as two degrees during an afternoon. The temperature inside the balance itself was measured by means of an Anschutz thermometer graduated in fifths of a degree which was clamped in a small ring-stand which stood inside the balance. The thermometer bulb was fixed as close as possible to the middle of the beam without touching it and the temperature was read through a magnifier without the balance doors being opened. The whole thermometer was completely inside the balance case.

TABLE 3

SENSITIVITY

Load	*Deflection sum − 0.1 mg.*	*Deflection sum*	*Deflection sum − 0.1 mg.*	*Temperature*	*Difference*	*Average*
0	+ 20, + 22	−83, −86	−192, −192	26.0	106, 107	107
500 mg.	+116, +118	+12, +12	− 93, − 99	26.2	106, 108	107
1 g.	+ 36, + 37	−65, −68	−179, −179	26.2	103, 112	107
10 g.	+ 25, + 27	−79, −81	−176, −180	26.2	106, 100	103
15 g.	+146, +146	+48, +50	− 59, − 61	26.3	97, 109	103
20 g.	+ 78, + 80	−22, −21	−122, −122	26.4	100, 100	100

The beam was released for each weighing so that the pointer oscillations were never greater than 100 nor less than 50 in the conventional style. Readings were taken beginning at the fifth reversing point at the left (*10*), the sixth at the right, and the seventh at the left. The beam was then arrested and the deflection sum was checked.

Determination of the Zero Point.—The balance was adjusted to a close zero point. At the start of the experiments successive values were −2, 0, −1, and −1 μg.

Determination of Sensitivity.—The sensitivity was determined according to Niederl (*11*) by shifting the rider one notch each side of the equilibrium position. The sensitivity was found to be above 100 and to decrease slightly with increasing load.

Determination of Precision in Weighing.—A platinum boat was weighed with a corresponding metal tare. Each time the rider was removed from the beam after arresting the balance. When it was replaced, the metal vee of the rider carrier was purposely placed a little to one side of the center of the notch before releasing so that the rider would roll slightly down the side of the notch. The object and the tare were each shifted on the pan and the balance was left for one minute with the doors open before taking the next reading. The average deviation of a single weighing from the series was calculated.

TABLE 4

Number	*Reading*	*Temperature*	*Number*	*Reading*	*Temperature*	*Mean*
1	+67	24.3	10	+67	25.4	69.9
	66	24.3		69	25.5	
2	72	24.2	11	67	25.6	
	72	24.2		69	25.6	Average deviation
3	76	24.4	12	70	25.6	2.6 micrograms
	78	24.4		70	25.6	
4	75	24.6	13	70	25.65	
	77	24.6		70	25.65	
5	71	24.8	14	70	25.7	
	70	24.8		73	25.8	
6	71	25.0	15	74	25.8	
	70	25.0		74	25.8	
7	65	25.2	16	67	25.8	
	65	25.2		67	25.8	
8	67	25.4	17	67	26.0	
	68	25.4		67	26.0	
9	69	25.4	18	67	26.0	
	68	25.4		67	26.0	

Determination of Equality of Notch Division.—Three calibrated quartz-stick riders were employed and were placed on the beam simultaneously in various notches. Starting at notches 0, 0.1, and 3.9 two of the riders were moved to 0.2 and 3.8, and so forth, and readings and temperatures were taken each time. No unusual differences were noted, indicating that the beam notches were evenly cut.

Determination of Period of Oscillation.—The period of oscillation between the fifth and sixth points of reversal was found to be eight seconds for a ten-gram load for the Ramberg balance. The Kuhlmann period for this corresponding amplitude was found to be seven seconds for a ten-gram load.

Determination of the Decrement of Amplitude.—The decrease of amplitude which is indicative of the amount of knife-edge friction was determined by following twelve swings after the fifth reversing point (Table 5). A decrement of six per cent. was noted as compared with a value of ten per cent. for our Kuhlmann determined by the same method. This means that friction of the knife edges in this balance is very small.

TABLE 5

Left	*Right*	*Sum*	*Quotient*	*Average*	*Per cent. of decrement*
−86	62	148	1.063	1.062	6.2
−82	57	139	1.085		
−78	53	131	1.040		
−74	49	123	1.060		
−70	46	116	1.054		
−67	43	110	1.069		
−63	40	103	1.061		
−60	37	97	1.065		
−58	33	91	1.058		
−55	31	86	1.062		

Picking Up the Rider.—It has been our experience when students who are learning to use the Ramberg balance knock the rider from the beam, that it can be most readily replaced as follows. The rider resting on the floor of the balance is transferred by the finger to a piece of chamois. It is then carefully cleaned by holding one end at a time in the forceps and wiping the other with the corner of the chamois folded over it. Next gripping the rider securely in its middle, the operator holds it in position within the rider-carrying device the wings of which are spread apart. After the wings are shut, the grip of the forceps is relaxed. With a little practice students are able to replace the rider themselves. This method is superior to that of attempting to drop the rider directly into a notch from the forceps.

A beginner must be cautioned to approach the rider from the side with the carrier. The wings should always be open. He should never lower the carrier directly from above the rider.

SUMMARY

1. The theory of the Ramberg quartz-stick rider as a solution for certain types of rider error has been discussed.

2. The new model Sartorius-Ramberg microchemical balance has been technically described.

3. The new model Sartorius-Ramberg microchemical balance responded favorably to the usual tests.

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CHEMISTRY *and the* COLLEGE *of* LIBERAL ARTS

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MUCH current criticism of higher education in America concerns the college of liberal arts. The lack of a guiding principle, the surrender to vocational fads, the dilution of course material, and the exaggeration of athletics do not greatly concern the professional institutes or the professional schools of the larger universities. It is important, therefore, to state the aims of the college of liberal arts, which was once, and can still be, the keystone of the educational system.

Almost everyone will agree that the aim of a college of liberal arts is to give a *general* education. This is helpful at least in a negative way because it simplifies the problem. The courses in the main should not be definitely professional.

In the writer's view the primary aims are fourfold. The first purpose of a liberal education should be to train the mind. To be sure, this is not a process which should start and stop with college. Habits of thought may be most easily inculcated during the high-school years and should there receive the greatest emphasis. But the aims of "progressive education" do not seem to include any form of mental discipline. The writer is aware that a psychological theory discredits the possibility of transferring acquired mental technics from one field of learning to another. A misunderstanding of the scope of this theory has done considerable harm to the progress of scientific teaching. The kind of mental training referred to by the writer is applicable to all conscious uses of the healthy human mind. A man is not necessarily a historian even if he has a good memory for dates. Training of the mind connotes, to use a homely phrase, training to put "two and two together." The trained mind can take apparently unrelated observations, induce such generalization as may be inherent in the data, and deduce the necessity for such observations as may be pertinent to the proof of his generalization. Such operations are as much the "method of everyday life" as they are the "method of science." It is sometimes difficult to make students, and others, realize that the untrained mind is less useful than the

unfilled mind. One of the duties of the educator is to make the mental training of a student as interesting and more significant than the physical training of an athlete.

A second aim of a liberal education is "to give the students knowledge of and respect for things of which the value is enduring, and has endured." These are the words of Lowell in "What a University President Has Learned." He does not say what these enduring things are. The writer conceives them to be such things as Christian ethics, political and religious freedom, and the common law. And surely no education is complete unless its students have also acquired health, tolerance, and courage, in so far as these virtues may be taught.

A third aim is to equip the students for living the life of their society. One might add, not only to live the life, but to live it constructively and enjoyably. This implies a great range of accomplishments, from being able to earn a living, to being able to enjoy the friendship of one's neighbors, from being able to lead one's fellow men along a path of constructive social effort to being able to enjoy a symphony.

The fourth aim of a liberal education may be summed up in the word "broadening." Why is travel considered to be educationally desirable? Because it "broadens" the individual. This means that the traveler sees that alien modes of life seem to work well, perhaps even better than his own. He sees where civilization may have stagnated, owing to resistance to change. He sees where nature has worked and is working her great marvels. No man should be considered educated until he has traveled extensively not only in the geographical world, but in the worlds of chemistry and of astronomy, and above all in the dimension of time, the record of man's accomplishments, for good or bad, through all recorded history.

While subscribing to President Hutchins' criticisms of the American university, the writer does not agree with his suggestions for modification of the curriculum. It is believed that a satisfactory curriculum may be constructed for achievement of the primary aims outlined above. In order to do so it is necessary to state to what aim each field of learning will contribute, and, if possible, to give a quantitative estimate of the contribution. For this purpose the writer has constructed a table. The four primary aims are abbreviated to (1) mind training, (2) enduring values, (3) living, and (4) broadening. However, in addition to these four, incidental but essential contributions are made by certain subjects. For instance, the *technic* of mathematics is necessary in order to understand physics, chemistry, astronomy, or modern economics. It is also desirable to be able to *communicate* with one's fellow men although this might be included under "living." At any rate, two categories have been added in the table. These are abbreviated to (5) technic, and (6) communication. An effort has been made to suggest quantitative significance by giving three stars for superlative performance in the manner popularized by motion picture critics. Finally, it should be added that the writer will be the first to admit that his table is, to say the least, open to argument.

TABLE 1

	Mind training	*Enduring values*	*Living*	*Broadening*	*Technic*	*Communication*
Anthropology (4)		x	x	xx		
Art and music (5)			xx	xx		x
Astronomy (5)	xx		x	xx		
Biological sciences (6)	xx		xx	xx		
Chemistry (7)	xxx		xx	xx		
Classics (5)	xx	x	x	x		
Economics (5)	x	x	x	xx		
English composition (7)	xx				xx	xxx
English literature (8)		xx	xxx	xxx		
Geological sciences (5)	x		xx	xx		
Modern language composition (5)	xx				x	xx
Modern foreign literature (7)		xx	xx	xxx		
History (8)		xxx	xx	xxx		
Mathematics (8)	xxx		x		xx	xx
Philosophy (9)	xx	xxx	x	xxx		
Physical education (3)			xxx			
Physics (6)	xxx		x	xx		
Political science and sociology (7)		xx	xxx	xx		
Psychology (6)	x		xx	xx		x
Public speaking (6)			xxx			xxx

The first conclusion to be drawn from the table is that a liberal education is only to be obtained by studying *all* the fields of learning commonly taught in colleges. The relative importance of the subjects is as follows.

(1) Philosophy;
(2) English literature, history, and mathematics;
(3) Chemistry, English composition, modern foreign literature, and political science and sociology;
(4) Biological sciences, physics, psychology, and public speaking;
(5) Art and music, astronomy, classics, economics, geological sciences, and modern language composition;
(6) Anthropology;
(7) Physical education.

The table should not necessarily be interpreted to mean that the most important subjects should be taught first, but that they should be taught most intensively.

It is suggested therefore that the basic liberal arts curriculum be made up as follows.

TABLE 2

Course	*Semester hours*
Philosophy	10
English literature	10
History	10
Mathematics	10
Natural science (general)	10
Special science	10
Modern foreign literature and composition	7½
English composition	5
Social sciences (general)	5
Special social science	5
Psychology	5
Public speaking	5
Classics	2½
Art and music	2½
Physical education	2½

This would leave from twenty to thirty hours available for specialization. The writer believes it to be an essential part of education that the student should study some subject intensively. Specialization is also a prerequisite for admittance to graduate schools.

Nothing has yet been said with regard to the educational value of extracurricular activities. These are no less important than the formal classroom work. The writer would insist that a good college of liberal arts should foster outdoor sports for all, student-faculty social relationships, amateur theatricals, student societies, and the like. He doubts the value of intercollegiate sports as now conducted, of fraternities, and of certain other aspects of collegiate life.

With regard to instructional methods in the college of liberal arts, the writer does not feel competent to say much except in relation to the teaching of chemistry and related sciences. This topic will be treated later. The writer does, however, agree with Lowell that "all true mental growth comes from self-education under guidance," and that one of the troubles with higher education is that "instead of applying the principle of self-education there has been too much dragging of youth over the ground in perambulators and wondering why their running does not improve."

It will have been observed that in the proposed curriculum there is much more natural science than is commonly required in liberal arts colleges. It is necessary, therefore, to defend the inclusion of what may never be of any "practical" use to the students. "Sir William Beveridge (of the London School of Economics) held the enlightened view that some of the students might benefit from a general introduction to natural knowledge." Sir William's views led to one of the finest books that has come to the writer's attention—Lancelot Hogben's "Science for the Citizen"— from which the above and the following three sentences are quotations.

"Natural science is an essential part of the education of a citizen because scientific discoveries affect the lives of everyone."

"'Science for the Citizen' is written for the large and growing number of intelligent adults who realize that the *impact* of *science* on *society* is now the focus of genuinely constructive social effort."

"It is also written for the large and growing number of adolescents, who realize that they will be the first victims of the new destructive powers of science misapplied."

"In the course of the last few centuries the scientific approach has been gaining acceptance as the guiding principle for the intellectual activities of Western man." (Gideonse in "The Higher Learning in a Democracy.")

"Modern education must put its main emphasis on the method of science." (Gideonse.)

"Education segregates the scientific specialist from those who study problems of government and social welfare." (Hogben.) What more important function can the college of liberal arts play than to see that the social scientist and the natural scientist are not separated too soon, and to see that there are men who understand the language and the methods of both?

"Science must be interested in the humanistic implications of the scientific habit of mind." (Gideonse.) *Society* must be interested in *all* implications of the scientific habit of mind.

The writer does not believe a student's time could be spent better than by reading "Science for the Citizen." There is enough material here to cover two years' work in the natural sciences. Such work should be followed by one or two years in a special branch of the sciences. This program would retain the virtues of both the historical and logical presentations of the sciences. As Hogben says, "Hence science for the citizen must be science as a record of the past and as an inventory for future human achievements. Inevitably it cannot be divorced from history." But the historical approach to science can also lead to great confusion in the student's mind. Just why both historical and logical approaches are necessary will be discussed later.

The writer believes that chemistry is able to make certain unique contributions to a liberal education. It may be taken for granted that the "broadening" influence is valuable. Every educated man should know something of atoms and molecules, of the structure of matter, of the great natural laws. What is even more important is the use of chemistry as a vehicle to demonstrate the operation of two aspects of the scientific method. The scientific method consists, in part at least, of the operations: (1) observation, (2) reflection, and (3) confirmatory observation, or considered action. These operations are inherent in practically all chemical progress. The writer does not believe there is any better place to train the mind in this aspect of the scientific method than the chemical laboratory. Through the use of carefully designed experiments the student is forced to conduct the three essential mental operations until they become part of his normal mode of thought. Precisely how such experiments may be designed is discussed later.

The other important aspect of the scientific mode of thought is the use of hypotheses and temporary approximations to the truth. Gideonse, in the "Higher Learning in a Democracy," criticizes the educational proposals of President Hutchins with particular reference to Aristotelian metaphysics as follows: "And so under the emotional seduction of having achieved absolute truth, an early and in itself noble stage of thought came to be considered the final stage of thought." This is precisely the difficulty that is so effectively combated by the historical approach to chemistry. Nowhere can such vivid presentation be made of the rise, triumph, and fall of beliefs concerning the nature of the universe. The importance in education is that here is repeatedly shown the slippery nature of absolute truth and the nevertheless great value of temporary approximations to the truth. The phlogiston theory in chemistry marked a great advance. Without it the next and current approximation to the nature of combustion might have been delayed a hundred years. But the phlogiston theory is now known to have been utterly false.

No matter how liberal it may be desired to keep the curriculum of a liberal arts college, nevertheless there is the fact that many students wish to go on to graduate

schools or to enter professional schools for which certain courses are prerequisite. As a tentative curriculum in chemistry the writer suggests a three-year course designed to follow at least one year of general science. Such a curriculum would include the following: one semester each of advanced general chemistry, of qualitative analysis, of quantitative analysis, and of inorganic chemistry; to be followed by a year each of organic and of physical chemistries.

It is now possible to summarize the objectives of the chemistry courses. First, to train the mind in the various aspects of the scientific method; second, to increase the student's power and enjoyment in the art of living; third, to broaden his horizon regarding the nature of the physical world; and fourth to equip him with such basic training as he may require for admittance to professional schools.

It remains to discuss the instructional methods suitable for the attainment of these objectives. These methods are considered at length in a paper by the writer entitled, "The Course in General Chemistry."[1] The following is, in part, a modified summary of what is contained in that paper.

It is clear that the objectives may be achieved only by a combination of lecture, recitation, and laboratory work. Generally speaking, the second, third, and fourth objectives mentioned are to be attained by suitable course content, but training of the mind is to be achieved by method of presentation.

In the matter of course content, certain criteria may be set up. These are

(1) Is the topic of general significance as regards all or at least many chemical phenomena?

(2) Does the topic touch everyday experience so closely as to arouse natural curiosity, or even so closely as to be taken for granted?

(3) Is the topic essential to what is generally discussed in the next courses in the subject?

(4) Can the student be expected to grasp the topic with his present factual and technical equipment?

However, inculcation of "scientific method" depends, not on course content, but on approach. In the lecture and recitation rooms efforts should be made to foster the scientific attitude by non-dogmatic presentation, by insistence on the occasional necessity for suspended judgment, and by written exercises designed to relate multiple observations by inductive thinking to general principles. But the best place to teach "scientific method" is in the laboratory. Here, too, the objective is to be achieved by *form* rather than by *content* of the experiments carried out. It is therefore possible to adopt experiments which achieve the minor objectives of the course provided they are adapted to the primary objective.

This adaptation may be done as follows. The first requirement is a clear, concise statement of the purpose of the experiment, followed by strict limitation of the work to that one purpose. The experiment must have an *end. The student should be able to do the experiment, or, better, solve the problem, with the mental and manual equipment already at his disposal.* He should not have to rely on instructor or text for information needed to complete understanding of the problem. He should go, like a research worker, with a certain amount of knowledge and he should ask of and receive from *nature* an extension of that knowledge.

The writer wishes to conclude with a reference to the use of research as an instructional device. "Is it not too much assumed that productive scholarship must be confined to the large universities and bodies organized for research?" (Lowell.) The small college can scarcely hope to compete with the large university in intrinsic value of the discoveries made. But in the small college, research is to be considered as primarily an instructional device rather than as a device for securing new knowledge. The educational values of research are to be found in the inspiration and training to be obtained by contact with men actively engaged in making discoveries. "A large part of educated American youth are trained in our colleges, where their attitude is largely determined by the intellectual enthusiasm of their teachers, and is not this spirit much heightened by the presence among those teachers of men flushed with the ardor of discovery?" (Lowell.)

In large universities the art of teaching is often neglected for the sake of research, and not even research as an educational tool, but as a means to promotion. The writer believes that small liberal arts colleges too often fail to see in research one of their most powerful instructional devices.

[1] SELWOOD, J. CHEM. EDUC., **16**, 466–71 (1939).

SUMMER COURSES IN CHEMICAL MICROSCOPY AT CORNELL

Instruction in chemical microscopy will be offered at Cornell University during the coming Summer Session. The introductory course includes work on micrometry and particle-size determination, optical properties of crystals and their behavior, lens systems, illumination, ultramicroscopy, photomicrography, and studies of textile and paper fibers. A course in microscopical inorganic qualitative analysis will also be given.

The session begins July 8th and continues for six weeks. By correspondence in advance, persons not desiring University credit may arrange to cover, in a shorter period, those portions of the field most suited to their needs. Inquiries should be addressed to C. W. Mason, Department of Chemistry, Cornell University, Ithaca, New York.

The VITAMIN C CONTENT *of* FRUITS *and* VEGETABLES

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INTRODUCTION

IN THE rather voluminous literature of this subject which has grown up in recent years, many factors, both external and internal, have been reported as affecting the Vitamin C (ascorbic acid) content of fruits and vegetables. Much of this work needs further confirmation. However, it is apparent that length of time and conditions of storage, methods of cooking and processing, variety, stage of development, climatic conditions, soils, and fertilizers must be regarded as of significance.

These factors affecting the quantity and stability of this vitamin, help explain why reliable investigators, using essentially the same method of determination, have recorded widely different quantities of ascorbic acid in the same kind of fruit or vegetable. For example, Floyd and Fraps (*11*) report two to six times as much ascorbic acid in cabbage as do Gould and Tressler (*13*). The results of Tripp, Satterfield, and Holmes (*20*), Maclinn (*16*), and Currence (*3*) with tomatoes might be cited as additional evidence. These investigators report quite different values even for the same variety. Smith and Fellers (*4*) find marked varietal differences in the Vitamin C content of apples.

That soils can affect Vitamin C content is substantiated by the work of Tressler, Mack, and King (*17*) who found that spinach grown on upland soil averaged fifty per cent. higher in Vitamin C than when grown on muck soil.

Few data are available concerning the effect of stage of development. For ten varieties of peas, average quantities of Vitamin C per gram fresh weight were 0.336, 0.272, and 0.205 milligram for immature, mature, and over-mature samples, respectively (*15*).

The literature of cooking and processing has been reviewed by Fixsen (*10*) and by Fellers (*5*). Recent investigations indicate that the most rapid loss of Vitamin C usually occurs during the first two minutes of cooking (*6*). Discarding the cooking water leads to further loss (*7*, *8*) which may be of considerable magnitude. (See Table 2.)

Storage conditions appear to be very important in determining the rapidity of Vitamin C loss. Spinach stored at 1° to 3°C. loses its Vitamin C content quite slowly; but at room temperature there is a fifty per cent. loss in three days and nearly a one hundred per cent. loss in seven days (*17*).

Fitzgerald and Fellers (*9*) recently report that fresh spinach on the Boston market varied from 0.15 milligram of ascorbic acid per gram in July to a maximum of 0.68 milligram per gram in November.

EXPERIMENTAL

It was thought that it would be interesting to compare the Vitamin C contents of several garden fresh vegetables with similar vegetables obtained from the open market. Later it was decided to include samples of certain other fruits and vegetables where comparisons between fresh and market samples could not be made, in order to obtain a rather inclusive list of ascorbic acid contents of fruits and vegetables in which the values were all determined by the same method and by the same investigator. The results of all these determinations are expressed in Table 1. Each value represents the average of at least two duplicate determinations on each of two separate samples.

In the course of the investigation some data were also accumulated on the effect of cooking on Vitamin C content. Girls from the School of Home Economics were told to cook known quantities of certain vegetables so as to obtain palatable preparations. The vitamin content of the fresh vegetable was determined immediately before cooking; and this was followed by a determination of the vitamin content of the cooked material, including the cooking water. The results of these experiments are given in Table 2.

For determining the ascorbic acid content, a modified Tillmans' method (*19*) was employed. This was essentially the same procedure that has been used successfully by Tressler (*18*) and his associates at the New York Agricultural Experiment Station. Results of such determinations have been found to check very satisfactorily with Vitamin C potency as determined by biological assay (*17*).

METHOD OF DETERMINATION

Two 20-gram samples of the plant material were ground in mortars with acid-washed sand and 30-cc. portions of one normal sulfuric acid which also contained two per cent. metaphosphoric acid (*12*). The latter forms catalytically inactive complexes with copper and iron ions, inactivates ascorbic acid oxidase, and functions as a general protein precipitant to yield a clear solution suitable for titration with the 2,6-dichlorophenol indophenol solution. The presence of strong acid also tends to inhibit rapid oxidative destruction of the vitamin; as well as to retard the reducing action of certain phenols, tannins, and glutathione which sometimes accompany the vitamin and which under favor-

TABLE 1

VITAMIN C CONTENT OF FRESH FRUITS AND VEGETABLES

Material	Variety	Source	Milligrams of ascorbic acid per gram fresh weight
Apple	Jonathan	Market	0.044
Apple	Wolfe River	Freshly picked	0.099
Asparagus	Mary Washington	Garden fresh	1.007
Asparagus	Unknown	Market	0.45
Avocado	Unknown	Market	0.279
Banana	Unknown	Market	0.284
Beans, Snap	Tendergreen	Garden fresh	0.453
Beans, Snap	Unknown	Market	0.195
Beans, Snap	Yellow Wax	Market	0.236
Broccoli	Italian Sprouting	Garden fresh	1.375
Broccoli	Italian Sprouting	Market	0.801
Brussel's Sprouts	Unknown	Market (Autumn)	1.846
Brussel's Sprouts	Unknown	Market (Winter)	1.19
Cabbage	Average for thirty varieties	Garden fresh	1.002
Carrot	Tendersweet	Garden fresh	0.111
Cauliflower	Primosnow	Garden fresh	0.960
Celery (blanched)	Salt Lake	Garden fresh	0.104
Chinese Cabbage	Unknown	Market	0.269
Chives	Unknown	Garden fresh	0.543
Cherry	Early Richmond	Freshly picked	1.386
Cress	Water-cress	Freshly picked	1.875
Cress	Water-cress	Market	0.600
Cucumber	Chinese	Garden fresh	0.107
Currant	Red Lake	Freshly picked	0.245
Dandelion	"Greens" (Spring)	Freshly picked	1.546
Dandelion	"Greens" (Summer)	Freshly picked	0.303
Egg Plant	Black King	Garden fresh	0.121
Endive (blanched)	Bavarian	Garden fresh	0.054
Endive (green)	Bavarian	Garden fresh	0.130
Garlic	Unknown	Market	0.139
Gooseberry	Poorman	Freshly picked	0.165
Grapefruit	Unknown	Market	0.364
Grape	Thompson Seedless	Market	0.055
Horseradish	Unknown	Garden fresh	1.224
Kale	Scotch	Market (Autumn)	1.877
Kale	Scotch	Market (Winter)	1.011
Kumquat	Unknown	Market	0.549
Leek (blanched)	Unknown	Market	0.180
Lettuce	California	Market	0.133
Lettuce	Hothouse	Q. S. U.	0.152
Lettuce	Mignonette	Garden fresh	0.205
Lettuce	Tennis Ball	Garden fresh	0.553
Lemon	"Sunkist"	Market	0.64
Lima Bean	Hopi	Garden fresh	0.296
Lime	Unknown	Market	0.398
Melon	Honeydew	Market	0.942
Melon, Musk	Polish No. 1	Garden fresh	0.374
Mustard Greens	Unknown	Market	1.790
Nasturtium Seeds	Unknown	Freshly picked	1.089
New Zealand Spinach	Unknown	Garden fresh	0.255
Okra	Long Green	Garden fresh	0.147
Onion	Brown	Mature	0.144
Orange	"Florida"	Market	0.360
Orange	Navel	Market	0.480
Parsley	Paramount	Garden fresh	1.094
Parsnip	Hollow Crown	Garden fresh	0.326
Paw-Paw	Wild	Freshly picked	0.360
Peach	Elberta	Market	0.084
Pear	Kieffer	Freshly picked	0.067
Pea	California Telephone	Market	0.214
Pea	Little Marvel	Garden fresh	1.028
Pepper (hot)	Hungarian Wax	Market	1.272
Pepper (green)	Windsor A	Garden fresh	0.976
Pepper (ripe)	Sunnybrook	Garden fresh	2.383
Potato	Early Ohio	Market	0.282
Radish	White Icicle	Market	0.261
Rhubarb	Flare	Garden fresh	0.444
Sage	Unknown	Garden fresh	0.250
Salsify	Sandwich Island	Market	0.073
Soy Bean (green)	Jogun	Freshly shelled	0.428
Soy Bean (green)	Bansei	Freshly shelled	0.404
Spinach	Unknown	Market	0.492
Spinach	Unknown	Garden fresh	1.123
Squash	White Bush	Market	0.232
Strawberry	Clermont	Freshly picked	1.429
Sweet Corn	Golden Bantam	Market	0.428
Sweet Corn	Stowell's Evergreen	Market	0.108
Sweet Potato	Jersey	Market	0.326
Swiss Chard (leaves)	Fordhook	Garden fresh	0.321
Swiss Chard (stems)	Fordhook	Garden fresh	0.075
Tangerine	Unknown	Market	0.484
Tomato (green)	Stokesdale	Garden fresh	0.180
Tomato (ripe)	Stokesdale	Garden fresh	0.36–0.57
Tomato (ripe)	Master Marglobe	Garden fresh	0.558
Tomato (ripe)	Small German Sugar	Garden fresh	0.72
Tomato (ripe)	Yellow Plum	Market	0.262
Tomato (ripe)	Unknown	Hothouse	0.200
Turnip	Shogoin	Garden fresh	0.240
Turnip Greens	Shogoin	Garden fresh	1.214
Zucchini	Unknown	Market	0.237

able conditions would react with the dichlorophenol indophenol solution.

After centrifuging, the residue was washed thoroughly with 30 and 20 cc. of the acid, centrifuging after each addition. The combined extracts were made up to exactly 100 cc. with distilled water and 10- or 20-cc. aliquots (which may be diluted to 50 cc. with eight per cent. acetic acid) were titrated with 2,6-dichlorophenol indophenol solution which had been previously standardized against pure ascorbic acid.

In instances where, due to the presence of anthocyanins, the dilution did not dispel a red or pink color which might be confused with the endpoint, aliquots were shaken with small quantities of Lloyd's reagent which was then removed by centrifuging (*2*). This removes a small quantity of the ascorbic acid as well, but was the best simple method of treatment that could be found for such solutions.

In actual determinations, 0.1 gram of the 2,6-dichlorophenol indophenol was weighed out, dissolved in small portions of hot water, filtered into a 200-cc. volumetric flask, cooled to room temperature, and made up to volume with distilled water. In the following discussion this is termed the dye solution. Fifty milligrams of pure ascorbic acid were then weighed out and made up to 200 cc. with the above-mentioned sulfuric-metaphosphoric acid solution. Ten-cc. portions of this Vitamin C solution were titrated with the dye solution until a faint pink color was observed which persisted for fifteen seconds. From the titration value,

TABLE 2

EFFECT OF COOKING ON THE VITAMIN C CONTENT OF VEGETABLES

Vegetable	Milligrams of ascorbic acid per gram fresh weight, uncooked	Per cent. loss of Vitamin C: Cooking water discarded	Per cent. loss of Vitamin C: Cooking water not discarded
Asparagus	0.83	26.5	15.0
Beans, Snap	0.455	26.7	12.5
Beans, Lima	0.297	42.2	17.5
Broccoli	1.625	61.7	45.3
Cabbage (shredded)	1.116	70.0	55.5
New Zealand "Spinach"	0.255	46.7	14.9
Peas	0.214	43.1	21.6
Swiss Chard (leaves)	0.355	67.8	47.3
Swiss Chard (stems)	0.075	58.2	44.8
Tomatoes	0.36	71.7	40.6
Turnip Greens	1.214	48.1	35.7

the number of milligrams of vitamin corresponding to a given volume of the dye can be readily determined. Then from the number of cc. of the dye solution which are required for the titration of an aliquot of the unknown solution, the Vitamin C content of the latter may be found.

The sulfuric-metaphosphoric acid solution must be freshly prepared each day. This is also true for the vitamin solution. The dye solution will keep several days but must be restandardized each day. After the solution has been kept for some time, the endpoint assumes a brownish tinge and becomes much less sharp. On standing, the metaphosphoric acid is probably changed to orthophosphoric which does not form catalytically inactive complexes with copper or oxidases that otherwise bring about a rapid destruction of the vitamin.

For materials suspected of containing appreciable quantities of reversibly oxidized ascorbic acid (which is physiologically available and hence must be determined to obtain the total Vitamin C content), aliquots of the extract should be diluted and treated by bubbling in hydrogen sulfide for ten minutes, followed by carbon dioxide for thirty minutes, or until a test for hydrogen sulfide is negative (*14*). This treatment reduces the reversibly oxidized vitamin (dehydro ascorbic acid) to ascorbic acid which will then react with the dye solution. In most instances, the reduction treatment was found unnecessary.

No appreciable destruction of the dye by the sulfuric acid used in extraction was observed (*1*) and the blanks were always very small.

SUMMARY

The Vitamin C contents of a large number of fruits and vegetables, all determined by the same method, are recorded.

Garden fresh specimens of fruits and vegetables contain considerably larger quantities of ascorbic acid than those obtained from the open market. The results here found, like some previous work reviewed in the introduction, indicate that natural variations are considerable; and contribute data which, with those of other investigators, may ultimately permit quantitative expressions of variability, and causes of variation.

From the results set forth in Table 2, it is apparent that a very considerable part of the loss of Vitamin C content that occurs on cooking is due to discarding the cooking water.

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SEMI-MICRO QUALITATIVE ANALYSIS *for* COLLEGE FRESHMEN

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ONE of the most important advances in the field of analytical chemistry within recent years is the work in microchemistry. Most of this was necessarily research, and where it was presented as instructional material, this presentation was to the advanced student of chemistry. It is interesting to note that microchemistry is growing fast and promises eventually to surpass macrochemistry in analytical deter-

minations. A. A. Benedetti-Pichler and J. R. Rachele (*1*) have a system for the analysis of the selenium group of Noyes and Bray. A. A. Benedetti-Pichler has published other microchemical methods of separation and identification of ions and has partially reviewed this in his article, "Qualitative Analysis of Microgram Samples" (*2*). Two papers which should increase the accuracy and speed of semi-micro or drop-reaction analysis are "Paper as a Medium for Analytical Reactions" by B. L. Clarke and H. W. Hermance (*3*) in which a more accurate delivery system is described for adding a given amount of reagent to a specific spot on the reaction paper, and "Applications of Confined Spot Tests in Analytical Chemistry" by Herman Yagoda (*4*). In this latter article is described a method of controlling the amount of spread that a drop will make on a filter paper by waxing the surrounding area. Two other papers which have general interest in microchemistry and give an outline of the growing importance of this field are "Recent Advances in Applied Microchemistry" by Joseph B. Niederl (*5*), and "General Microchemistry" by A. A. Benedetti-Pichler (*6*). All of these publications point to the growing interest and general analytical application of microchemistry.

With the introduction and refinement of the semi-micro or drop-reaction method of qualitative analysis, it appeared that it could be used in place of the more classical macro method for the last semester of freshman college chemistry laboratory. This change would be desirable from many standpoints. It would alleviate the clouded, smoke-filled qualitative laboratory, and in this way make chemistry more useful as one of the general cultural sciences. This would achieve much toward placing chemistry on the popular basis which its present industrial and economic importance warrants. Another objection to qualitative laboratory work is the relatively large proportion of time which is spent on the purely mechanical processes of filtration, saturating with a gas, and washing of precipitates. A benefit accorded the student and the administration is the relatively lower breakage cost to the former, and the smaller quantities of reagents used in the semi-micro system. Perhaps the greatest benefit is the relatively more up-to-date procedure which should make the student more valuable in the industrial or research laboratory (*7*).

With these as goals, it seemed worth while to test the relative effectiveness, in the laboratory, of the semi-micro and the macro method of qualitative analysis for the presentation of a course in chemistry to a class of college freshmen. With this study as the purpose, the class was divided so that there were about one-half of the students doing the laboratory work by the macro method and the other half were using the semi-micro procedure. In this division of the class, care was taken to get an average group of students to carry out the work by the semi-micro method. To do this use was made of the student rating of their relative chemical aptitude as shown by the "Iowa Placement Examination" constructed by G. D. Stoddard, L. W. Miller, and Jacob Cornog (*9*), and the ratings shown by the relative class rank of the semester examination covering the first half of the course. This was an objective test of my own devising, but it was previously used and corrected to some extent for ambiguities. There were fourteen students who completed the full second semester's work. Only one dropped the subject during this period. He had no apparent interest in any of his subjects, and since he did no work in the chemistry laboratory after the first six weeks, no data are given in this study for him.

The relative student rank which was used in selecting the students for the two sections is given in Table 1.

TABLE 1

STUDENT RANK IN APTITUDE AND FIRST SEMESTER EXAMINATION

Student number	*Aptitude percentile rank (9)*	*Semester examination class rank*	*Average class rank*
43	92	1	1
44	15	14	14
45	85	5	4
46	50	7	8
47	50	9	9
48	50	13	10
49	27	10	11
50	53	10	8
51*	70	2	2
52*	50	4	6
53*	50	12	12
54*	60	6	5
55*	20	8	10
56*	70	3	3

* Semi-micro method used by these students.

Students numbers 43, 44, 45, 46, 47, 48, 49, and 50 were included in the group using the macro method of analysis. This included students at both extremes of the class in relationship to their chemical aptitudes. The average of their scores places this group in the fiftieth percentile. This would indicate that there is no undue weighting with exceptional or poor students. The average ranking of this group by the scores obtained in the semester examination was seven, which

TABLE 2

AVERAGE STUDENT RANKING OF SECTION A AND OF SECTION B

Section	*Aptitude score*	*Percentile rank (9)*	*Examination score*	*Examination median score*
A	38	50	74	73
B	39	53	77	73

was the median for the entire class. These data would indicate that the students in the macro system of analysis were as near the normal in native ability and application as it was possible to obtain. (We shall refer to the students doing the qualitative analysis according to the macro method as section A.)

Students numbers 51, 52, 53, 54, 55, and 56 were included in the group using the semi-micro method of analysis. (We shall refer to this group as section B.) These students were within the average in native ability as shown by their percentile rank. The rank in the first semester examination for this section was a little higher than the median for the entire class.

The comparisons of these two groups are better shown by collecting the data into compact tabular form.

TABLE 3

TESTS USED IN THE SEMI-MICRO ANALYSIS

Ions	*General precipitant*	*Confirmatory test*	*Remarks*
Silver	HCl acid	$AgCl$	Dissolved by ammonium hydroxide and reprecipitated by adding nitric acid
Lead	HCl acid H_2S acid	$PbCrO_4$ $PbCrO_4$	This covers the reactions for the lead which comes down as the chloride and also as the sulfide
Mercurous mercury	HCl acid	Aqua regia to $HgCl_2$ plus $SnCl_2$	The mercurous mercury is oxidized to the mercuric form by means of aqua regia and the resulting chloride reduced to the mercurous chloride and mercury by stannous chloride
Mercuric mercury	H_2S acid	Hg_2Cl_2	
Bismuth	H_2S acid	Metallic bismuth	Bismuth hydroxide is reduced to the black metallic bismuth by sodium stannite
Copper	H_2S acid	$Cu_2Fe(CN)_6$	Tested in the presence of cadmium
Cadmium	H_2S acid	CdS	Copper is removed by treating with potassium cyanide
Arsenic	H_2S acid	Gutzeit	Separated from the copper group by sodium polysulfide. Where there was an appreciable amount present the yellow sulfide was used as the confirmatory test
Antimony	H_2S acid	Sb_2OS_2	There was not complete satisfaction with this test as we used it. The separation from the copper group is described under arsenic
Tin	H_2S acid	$SnCl_2$ plus $HgCl_2$	Reduction of the tin was carried out by reacting magnesium dust with a dilute acid. Considerable care needs to be exercised here
Iron	NH_4OH	$Fe_4(Fe(CN)_6)_3$	Interfering anions are removed and the cations are oxidized to their higher valences by boiling the solution with bromine
Chromium	NH_4OH	$PbCrO_4$	The use of the perchromic acid test would be desirable here, but it has not been successful
Aluminum	NH_4OH	$Al(OH)_3$ aluminon	Adsorption of the dye, aluminon, to $Al(OH)_3$ precipitate
Manganese	NH_4OH and some with $(NH_4)_2S$	$NaMnO_4$	The precipitated oxide and hydroxide are treated with sodium bismuthate
Nickel	$(NH_4)_2S$	Nickel dimethylglyoxime	This is probably one of the most sensitive tests for nickel, and its success warrants the use of such a complex ion
Cobalt	$(NH_4)_2S$	Cobaltic alpha-nitroso-beta-naphthol	As for nickel
Zinc	$(NH_4)_2S$	$Zn_2Fe(CN)_6$	The confirmatory compound produced in the presence of Orange IV gives a yellowish green coloration
Barium	$(NH_4)_2CO_3$	$BaCrO_4$ and flame test	
Strontium	$(NH_4)_2CO_3$	$SrSO_4$ and flame test	
Calcium	$(NH_4)_2CO_3$	CaC_2O_4 and flame test	The nitrate is produced and dissolved in absolute acetone
Magnesium	.....	$MgNH_4PO_4$	
Potassium	.....	$K_2NaCo(NO_2)_6$	Excess ammonium ion must be removed
Sodium	.....	Sodium zinc uranyl acetate	Phosphates, and so forth, must be removed, or they interfere with the test
Ammonium	.....	Action of vapors on moistened litmus	Some of the water solution of the original sample is made strongly alkaline with sodium hydroxide and heated

All the scores given in Table 2 are averages of the group for which they are registered. This does not make them exactly authentic, and they are grouped in this way only for the purpose of comparison. These data show that the two sections are quite comparable in natural ability and application.

The text chosen for section B was "Semi-micro Qualitative Analysis" by Engelder, Dunkelberger, and Schiller (*8*). This text was written with a view to use by more advanced students, and it was necessary to limit the tests for the ions. For this reason one test for each ion was chosen from the list suggested and this test was used consistently by the students. For each ion that test was chosen whose reaction was within the range of the student's ability to represent by chemical equations. Occasionally, however, it was necessary to use a more complex reagent such as the test for nickel, for which dimethylglyoxime was used, and cobalt, for which alpha-nitroso-beta-naphthol was used. A very brief consideration of the types of tests used are given in Table 3.

This table will indicate that there have been no radical departures from the macrochemical reactions. The main changes are in the method of carrying out these reactions. No emphasis was placed on the anion analysis and the method described in the text for systematic identification was used The text used by section A was "Introduction to Qualitative Analysis" by Jacob Cornog and W. C. Vosburgh (*11*). There were no modifications used in the procedure, except that a test for the phosphate ion was added.

The method of instruction used was to have the student run preliminary tests in each of the five groups. All the ions for a given group were present, and the student was required to obtain good confirmatory tests before he was allowed to go on to the next group. In this way the student had first-hand experience and information on what to expect in a routine experiment. After this preliminary work, each student was given two unknowns in solution. These solutions contained the ions in approximately 2 *M* concentration. Students of section B were given 1 ml. of sample for their analyses and those of section A were given 20 ml. This makes a range of from 0.05 gm. to 0.1 gm. for section B, and 1.0 gm. to 2.0 gm. for section A. The third unknown was analyzed for the anions only. The samples were of the same relative size as described above. Section A analyzed for the carbonate, nitrate, sulfate, silicate, chloride, and phosphate. Section B analyzed for cyanide, nitrite, sulfide, thiosulfate, sulfite, carbonate, arsenite, arsenate, phosphate, fluoride, sulfate, borate, oxalate, tartrates, chromates, ferrocyanides, ferricyanides, thiocyanates, iodides, bromides, chlorides, acetates, and nitrates. While section B was required to run the analysis for the list of anions given above, no emphasis was placed upon any except the more common ones such as are listed under section A and those which might interfere with the cation analysis.

The fourth unknown was a solid, which frequently required fusion before it could be brought into solution.

The size of the sample was about 0.25 gm. for the students of section B, and from 5 to 10 gm. for those of section A. This was analyzed for both the cations and the anions. The fifth experiment was the preparation of a commercial product. The formulas used were those in "Chemical Formulary," Volume III, edited by H. Bennett (*10*). The sixth experiment was an analysis of a comparable commercial product, in which the details for the identification of such organic compounds as were present were given to the individual student as he required them. These directions were gathered from various sources of which "Standard Methods of Chemical Analysis" by W. W. Scott (*12*) and "A Systematic Identification of Organic Compounds" by R. L. Shriner and R. C. Fuson (*13*) were the most useful references at hand. The results in the two groups which were obtained by this method of instruction are given in a compact form in Tables 4 and 5.

TABLE 4

RESULTS OBTAINED IN QUALITATIVE ANALYSIS BY SECTION B

Student number	*Laboratory hours*	*Cations reported*	*Anions reported*	*Total ions present*	*Percentage of ions found*
51	90	22	19	51	80
52	95	22	7	54	54
53	100	25	17	55	76
54	105	21	4	33	76
55	100	32	17	62	79
56	94	28	13	58	71
Average	97	25	13	52	73

TABLE 5

RESULTS OBTAINED IN QUALITATIVE ANALYSIS BY SECTION A

Student number	*Laboratory hours*	*Cations reported*	*Anions reported*	*Total ions present*	*Percentage of ions found*
43	106	24	4	35	80
44*	100	5	..	..	..
45	103	20	5	38	66
46	100	16	3	29	66
47	118	28	3	41	76
48	100	31	4	40	88
49	108	12	4	29	55
50	108	5	4	26	35
Average	105	18	4	34	67

* Much undirected work due to lack of ability.

From these data it is worth noting that the students in section B did one and one-half times as much work in the laboratory within a shorter time and with more satisfactory results than the students in section A. Since these two sections differed only slightly in their native ability and application as shown in Tables 1 and 2, these results must be attributable to the greater effectiveness of the semi-micro method of analysis.

An important consideration in a study of this type was the student reaction to the different working conditions. There were few, if any, of the section B students who entered the laboratory for the second semester's work with any marked degree of enthusiasm.[1] In fact they rather resented the part of "guinea pigs" which they considered they were playing. It required about three weeks of laboratory work to convince them that they really had the better end of the bargain. It then became difficult to keep the students in section A from feeling somewhat abused. In fact, all the students in the laboratory were very much "sold" on the semi-micro method.

It is also an important consideration in the smaller colleges and high schools that the unpleasant odors of the chemistry laboratory be kept at a minimum. In the macro method of analysis this was a major problem, as it was frequently necessary for the student to boil off hydrogen sulfide and sublime some ammonium chloride by baking. Four or five students carrying out these operations simultaneously overloads the normal ventilating system and clouds the laboratory and much of the school building within a very short time. In the semi-micro method the amount of these gases or fine particled solids were so slight that they could be readily removed.

The economical administration of a chemistry course is also one of major importance to the small college and high school. Considering the breakage cost per student per semester, the average for section B students was approximately sixty cents; for section A one dollar and twenty-five cents. Administration costs for section A were approximately three dollars and fifty cents per student per semester, compared to two dollars for section B.

There remains the consideration of the comparative general instructional value of the two methods used for the laboratory work. The best comparison which we have is the relative rank of the students in their aptitude tests and in their semester examinations. These comparisons are given in Tables 6 and 7.

TABLE 6

COMPARISON OF THE RANKS IN THE CLASS OF SECTION B STUDENTS IN THEIR APTITUDE, AND FIRST AND SECOND SEMESTER EXAMINATIONS

Student number	*Aptitude percentile rank*	*First semester examination rank*	*Second semester examination rank*	*Qualitative analysis rank*
51	70	2	2	2
52	50	4	9	12
53	50	12	12	5
54	60	6	7	7
55	20	8	3	4
56	70	3	6	8
Average	53	5	6	7

TABLE 7

COMPARISONS OF THE RANKS IN THE CLASS OF SECTION A STUDENTS IN THEIR APTITUDE, AND FIRST AND SECOND SEMESTER EXAMINATIONS

Student number	*Aptitude percentile rank*	*First semester examination rank*	*Second semester examination rank*	*Qualitative analysis rank*
43	92	1	1	3
44	15	14	14	14
45	85	5	5	9
46	50	7	8	10
47	50	9	11	6
48	50	13	4	1
49	27	10	10	11
50	53	10	13	13
Average	50	7	8	10

These results show that the students in section B have retained the small advantage which they possessed over section A and have been able to add a little more to this advantage. These results are not so much

[1] Many of the errors and steps needing special attention are given by G. W. SMITH in his article, "Teaching of qualitative analysis by the semi-micro method," J. CHEM. EDUC., **15**, 324 (1938).

different that they would warrant the claim that the use of the semi-micro method used in the laboratory increases the instructional value of a course to freshman college chemistry students. They do warrant the statement that the use of the semi-micro method is as effective in the freshman chemistry course as was the macro method of analysis.

For these reasons it is obvious that the introduction of the semi-micro method of qualitative analysis into the college freshman chemistry laboratory tends to (*a*) make the general chemistry laboratory a more congenial place for the student to work, (*b*) eliminate much of the time-consuming, purely mechanical processes, (*c*) save the student in general breakage costs and the administration in general supply costs, and (*d*) introduce the student to the more modern and usable methods of industrial and research laboratories. These are the benefits to be derived from the adoption of the semi-micro qualitative analysis for the second semester's work for the college freshman chemistry course which includes a semester of qualitative chemical reactions in the laboratory. There are no apparent drawbacks to the use of this method.

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The SIMPLIFICATION *of* CERTAIN CALCULATIONS BASED *on the* MASS LAW

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IN CASES where the utmost accuracy is not necessary in mass law calculations, certain simplifications are in order. Thus, one commonly uses stoichiometric concentrations instead of activities, especially in such instances where activity coefficients are unknown and may not be readily or accurately determined. If this is done, the accuracy of such computations is lowered to an extent which depends on the numerical values of the ignored coefficients and their arrangement in the mass law equation.

Granting that circumstances exist, which limit the exactness desired or possible in such calculations, one may, in addition to using concentrations instead of activities, simplify the mathematical equations to a degree consistent with this reduction in accuracy. The equations for dissociation and hydrolysis, in particular, may be easily treated in this fashion.

Let us consider the case of a simple dissociation. The mass law expression, based on concentrations, for the reaction $AB \rightleftharpoons A + B$ is:

$$K = \frac{(A)(B)}{(AB)} \tag{1}$$

If C_0 is the original concentration before dissociation occurs, and $(C_0 - x)$ is the equilibrium value and if there is no common material from another source, equation (1) becomes:

$$K = \frac{x^2}{C_0 - x} \tag{2}$$

On solving by means of the quadratic formula, one obtains as the only physically acceptable solution:

$$x = \frac{-K + \sqrt{K^2 + 4K \cdot C_0}}{2} \tag{3}$$

or

$$x = \frac{-K}{2} + \sqrt{\frac{K^2}{4} + K \cdot C_0} \tag{4}$$

These equations are particularly suitable for dissociations of weak electrolytes in aqueous solution, equation

(4) being given by Kolthoff and Sandell[1] and others for the dissociation of a weak acid or base.

Equation (3) may be simplified in a manner similar to that to be given below for the more common and useful equation (4). The latter may be rearranged as follows:

$$x = \frac{-K}{2}\left(1 - \sqrt{1 - 4C_0/K}\right) \qquad (5)$$

Now if $\frac{C_0}{K} \geq 25$, the first term under the radical obviously cannot exceed in value one per cent. of the second term under the radical, and may be dropped, if no greater accuracy than this is required in the final answer. This being so, equation (5) may be written:

$$x \leqq \frac{-K}{2}\left(1 - \sqrt{4C_0/K}\right) \qquad (6)$$

or

$$x \leqq \frac{-K}{2} + \sqrt{K \cdot C_0} \qquad (7)$$

This is a very useful equation for solving dissociation problems in elementary quantitative analysis, but cannot be found in the textbooks on that subject. If, however, $\frac{C_0}{K} \geq 2500$, the value of the square root term in equation (5) becomes ≥ 100, and the first term may be dropped, as it cannot be greater than one per cent. of this. Equations (5) and (7) may now be reduced to the expression:

$$x \leqq \sqrt{K \cdot C_0} \qquad (8)$$

Such an equation is very commonly used for the dissociation of weak acids or bases in aqueous solution, being $(H^+) = \sqrt{K_a \cdot C_0}$ and $(OH^-) = \sqrt{K_b \cdot C_0}$, respectively, in these two instances.

The extent of dissociation of a substance is greater the less the concentration and the greater the dissociation constant, other factors being fixed, and it should be noted that these things were quantitatively considered in deriving equations (7) and (8).

The use of the figure one per cent. above is arbitary, and one should actually use that value which is consistent with the desired or attainable accuracy. The error incurred by using concentrations instead of activities is frequently as high as several per cent. and can be greater as, for example, in concentrated solutions of electrolytes.

Hydrolysis equations lead to mass law expressions of the same form as those given above for dissociation, and if the same limitations and simplifications obtain, equations (4), (7), or (8) may be used, provided that K is replaced by K_h, the hydrolysis constant. Thus equation (8) would be $x \leqq \sqrt{K_h \cdot C_0}$ which conforms to the equation $(H^+) = \sqrt{\frac{K_w}{K_b} \cdot C_0}$ which is usually given for a solution of a salt of the "strong acid-weak base" type and $(OH^-) = \sqrt{\frac{K_w}{K_a} \cdot C_0}$ which is commonly used for a salt of the "weak acid-strong base" type.

SUMMARY

Simplified solutions for the mass law expressions for dissociation and hydrolysis have been derived, some of which are new.

Conditions are given which permit one to know when the simplified equations may be used. This had not been done rigorously before.

[1] KOLTHOFF AND SANDELL, "Textbook of quantitative inorganic analysis," The Macmillan Co., New York City, **1936**, p. 37, equations 5 and 6, p. 39.

A LANTERN DEMONSTRATION *of a* ROTATING-VIBRATING DIATOMIC MOLECULE

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HAZELHURST[1] describes a model by which rotation, vibration, and rotation-vibration motions of diatomic molecules consisting of two dissimilar atoms can be represented. This model has a rather complicated system of pulley drives, and at the same time it is such that it can only be demonstrated with advantage to a small number of people at any one time.

By using the basic principle of Hazelhurst's model, a lantern slide has been prepared which may be used to demonstrate vibration and rotation-vibration, and, by

[1] J. CHEM. EDUC., **12**, 353 (1935).

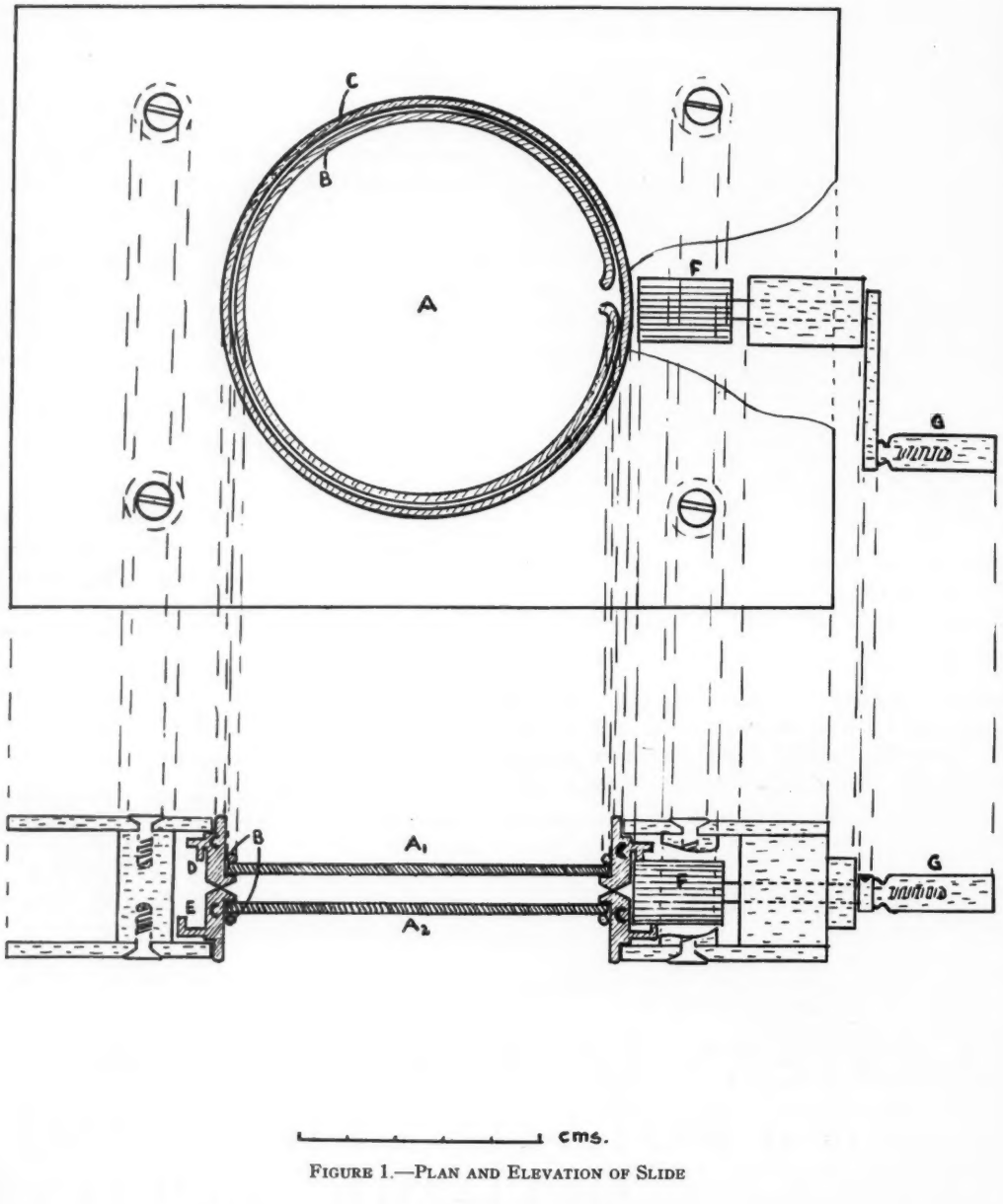

FIGURE 1.—PLAN AND ELEVATION OF SLIDE

a simple alteration, rotation motions. This simplified model loses the variety of speed ratios of rotation to vibration which can be obtained with the original model. On the other hand, it may be recommended strongly on the grounds that it shows clearly the principles of the motions, and the way in which rotation-vibration is derived; and that it can be demonstrated satisfactorily to any audience, no matter how large.

Figure 1 illustrates the construction of the model. Two circular glass plates A_1, A_2, are mounted by brass wire springs B in rims C which are fitted with rack gears, D, E, and are themselves mounted and free to rotate in the two faces of a rackwork lantern slide. The radius of the rack gear D on one rim is slightly smaller than that of the other, E. A pinion, F, is mounted on a handle G which slides through a short distance. When the handle is pulled out, the pinion engages with the rack of greater radius alone. When it is pushed in, the pinion rotates both racks in opposite directions.

Friction between the two rims is reduced to a minimum, while the friction between the rim and the face of the slide is kept considerably larger. This is to prevent the loose plate from being turned by the moving one

when the handle is pulled out. Alternatively a catch may be provided to lock the loose plate in position when necessary (not shown in Figure 1).

The two glass plates are coated with a suitable black paint. When this is dry, the lines on each face are cleared by means of a scriber or other pointed instrument. These diagrams (Figure 2) are similar to those used by Hazelhurst for his model. On one plate are two epicycloids plotted with opposite signs, while on the other are two straight radial lines placed so that when the two discs are in position one of the lines just covers the variation of the outer orbit, and the other covers the variation of the inner orbit.

By placing the slide in a lantern, two spots of light are seen on the screen. It is usually preferable to

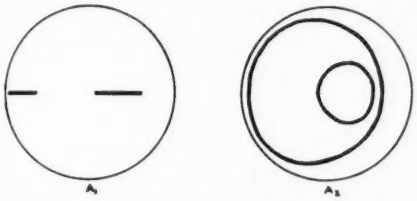

FIGURE 2.—GLASS PLATES

throw the slide slightly out of focus. On keeping the handle pulled out and rotating it, the spots of light vibrate about an unsymmetrically placed center. When the handle is pushed in, the vibratory motion passes into rotation-vibration. By turning the handle slowly this transition may be seen clearly, and by hastening the speed of rotation it is possible to impart a good idea of the actual orbits of the two atoms. Pure rotation is obtained by clipping both discs in one mount. The depth of the mount allows this to be done.

The model has, of course, a similar limitation to that of Hazelhurst, in that the molecule which is represented must be unsymmetrical, otherwise the orbits would cross. But several molecules with different amounts of unsymmetry may be represented by using several sets of glasses carrying different curves.

The difference in size of the two atoms may be represented to some extent by making the lines which produce the spot of light representing the heavier atom thicker than the others. This must not, however, be emphasized too much, as otherwise the slide cannot be thrown sufficiently out of focus without weakening unduly the spot of light representing the smaller atom.

SUMMARY

A simple rackwork slide which represents rotation, vibration, and rotation-vibration in unsymmetrical diatomic molecules is described. With this, the motions and their relation to each other may be portrayed to large audiences.

ACKNOWLEDGMENT

The author wishes to thank the Workshop of the Physics Department of this University, where the model described was constructed.

A NOTE ON THE NORMAL MELTING AND BOILING POINTS OF IODINE

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THERE seems to be an unduly widespread opinion that iodine cannot be melted or boiled at atmospheric pressure, or at least in a vessel open to the atmosphere. For example, Marsh states, "The vapor pressure of solids at ordinary temperatures is not always small. Iodine, for example, attains a vapor pressure equal to atmospheric before it melts and can, therefore, be distilled directly from the solid."[1] This prevalent misconception is probably due to the fact that when solid iodine is heated in an open vessel, vaporization without fusion or boiling is ordinarily observed.

An examination of sublimation and vapor pressure data[2] reveals that the above quoted statement is incorrect, and one should expect to be able to realize the normal melting and boiling points, for the sublimation pressure reaches a maximum value of only approximately 90 mm. of mercury at its melting point. The subsequent simple procedure will serve to clarify the situation.

EXPERIMENTAL

Place a sample of iodine in an ordinary test-tube and draw out the end of the tube until the opening does not exceed a few mm. in diameter. If heat is now applied, fusion and boiling can be seen to take place.

CONCLUSION

It seems that the reason for the usual non-observance of these phenomena lies in the fact that although the solid, when heated in an open container, exerts a sublimation pressure much less than atmospheric, it, nevertheless, attains such a high value that the solid may be completely vaporized into the surroundings before the melting or boiling points are reached, if the vessel is too open. If vapor losses are reduced by restricting the opening of the container, less of the solid phase will be vaporized in the tendency to attain equilibrium between the solid and vapor phases. By such means, the solid form can be retained until fusion and boiling are realized.

[1] MARSH, "Principles of phase diagrams," McGraw-Hill Book Co., Inc., New York City, 1935, p. 35.

[2] See, for example, the "International Critical Tables," McGraw-Hill Book Co., Inc., New York City, 1938, Vol. III, p. 201.

METALLURGY *of* TUNGSTEN *and* MOLYBDENUM[1]

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WHILE the two metals, tungsten and molybdenum, may indeed be grouped with the "less familiar elements," this classification might be questioned by a considerable group of individuals who are engaged in the manufacture of alloy steels, incandescent electric lamps, or certain other electrical appliances.

Tungsten and molybdenum are naturally classed together because of certain marked similarities in behavior when used as alloying elements as might be expected from their adjacent positions in the periodic table. The refining processes employed in the metallurgy of these elements depend, of course, upon the ultimate uses of the metals, and the high purity products such as the rod, wire, or ribbon used in various applications by the electrical industry require most careful treatment. High purity in these metals is demanded not only for the service requirements of the finished product, but likewise by the working processes by which their fabrication is completed. Since the interest of this symposium is presumably centered upon the less familiar aspects of the metals under discussion, I shall devote my attention to methods used in the production of high purity tungsten and molybdenum as ductile wire or sheet. Both metals are pioneers in the field of so-called "Powder Metallurgy" which term describes the technic of forming or fabricating a metal or alloy which has never been in a molten condition. The process as applied to tungsten was born of necessity, since the extremely high melting point, 3400°C., precluded a possibility of obtaining this metal from a molten state with any degree of purity. On the other hand, this same high melting point, together with a low vapor pressure, were the very properties desired in a material to serve as the filament for an incandescent lamp. A powerful incentive, therefore, existed for the development of a commercial process for producing tungsten in the form of ductile wire.

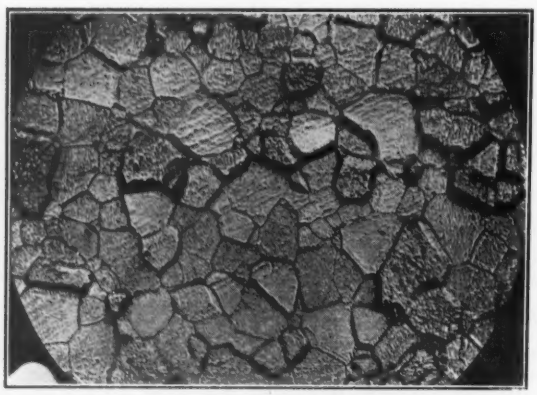

FIGURE 1.—MICROSTRUCTURE OF "TREATED" TUNGSTEN ROD. × 200

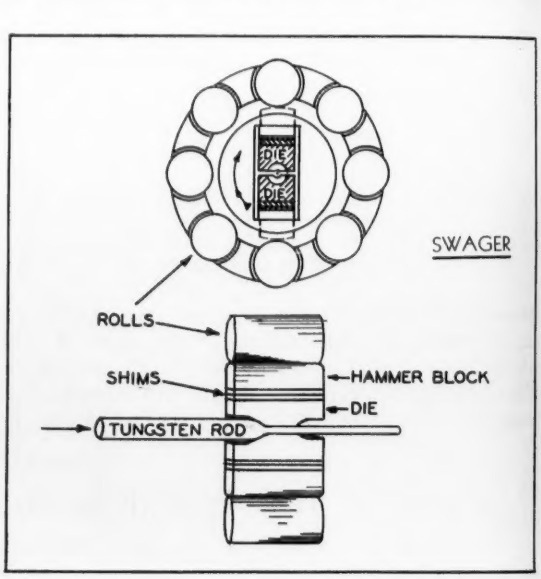

FIGURE 2.—DIAGRAMMATIC DRAWING OF SWAGER

The earliest tungsten wires were formed from the metal powder, obtained by reducing the purified oxide in a stream of hydrogen at about 800°C. This powder, mixed as a paste with an organic binder, was forced through a die under high pressure. The resulting thread was first heated in a reducing atmosphere at a temperature sufficiently high to decompose and volatilize the binding material, then baked or sintered at a higher temperature, producing a wire of sufficient strength to be mounted in a lamp. While brittle at room temperature such tungsten wire could be easily bent when heated to redness. This observation sug-

[1] Presented at the Second Annual Symposium of the Division of Physical and Inorganic Chemistry on the Less Familiar Elements, Cleveland, Ohio, Dec. 27, 28, and 29, 1937.

gested the possibility of hot-drawing such a wire to smaller diameters.

After many trials such reduction by drawing was accomplished in 1908 by Dr. W. D. Coolidge at the Research Laboratories of the General Electric Company. In order to prevent breakage in drawing it was found necessary to apply heat not only to the wire entering the die, but also to the die itself and to the pliers that gripped the forward end of the wire. After passing through a few dies, the wire became less brittle and could actually be bent at room temperature without breaking.

These experiments formed the basis for the present method of working tungsten, by which, each month, many miles of wire are drawn to a diameter as small as that of the human hair.

When the metal is to be used as a lamp filament the nature of the tungsten ore is a matter of prime importance since certain elements when present as impurities are difficult of separation and interfere not only with the working properties of the metal but also its performance in the lamp. At the present time the tungsten used in the lamp industry is extracted by wet methods from an ore of the Wolframite type, which is a tungstate of iron and manganese. The purification process involves precipitations and crystallizations, the final product being the tungsten metal powder, hydrogen, reduced from an oxide at a temperature of some 850°C.

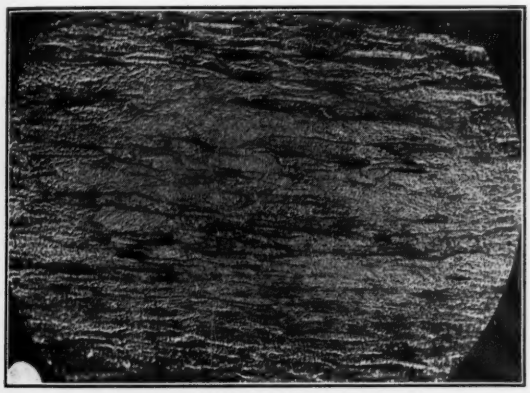

Figure 3.—Microstructure of Tungsten Rod after a Fifty Per Cent. Reduction in Area by Swaging

After mixing and sifting through fine bolting cloth the metal powder is loaded into a steel mold and compressed at about twenty tons per square inch to form a bar one-half to three-quarters of an inch square and twenty-four inches long. Usually no binder is added to the powder before pressing and the bar is distinctly fragile as taken from the mold. With care, however, it may be transferred to a slab of tungsten or molybdenum and upon this slab slowly stoked through a furnace at about 1300°C., protected from oxidation by an atmosphere of hydrogen. This furnace consists essentially of an alundum muffle wound with a resistor of tungsten or molybdenum wire and equipped with a water-cooled chamber at the discharge end within which the tungsten bar is allowed to cool in hydrogen. Some strength is imparted to the pressed bar by this so-called "sintering" operation, but the volume shrinkage is slight and the density is about 12 as compared to that of 19 shown by the metal after working.

The bar is now ready for the high temperature treatment necessary to fit it for subsequent working. In this operation, known in the shop as "treating," the sintered tungsten bar is suspended from a water-cooled clamp lined with tungsten slabs for electrical contacts. Its lower end is gripped by another set of tungsten contacts that are partially immersed in a water-cooled well of mercury. A cooled copper hood is lowered over the suspended bar, dipping into a ring seal of mercury and a stream of hydrogen is passed through the interior of the hood. The temperature of the tungsten bar is now slowly raised by increasing the voltage in the circuit of which it forms a part. Control of this heating operation is based upon the predetermined amperage required to fuse a bar of known weight and dimensions. For some fifteen minutes the current through the rod is maintained at ninety-five per cent. of the so-called "fusion amperage" which may represent several thousand amperes. During this period the temperature of the tungsten approximates 3200°C. as determined by the relationship between temperature and voltage. A linear shrinkage of some fifteen per cent. results from this treatment and the density increases to 17 or 18.

The fracture of the metal bar is now crystalline in appearance, and the microstructure resembles that of a cast metal which has been worked and subsequently recrystallized by annealing. Such a structure is shown in Figure 1 which was selected to illustrate the intergranular path of rupture which results from any attempt to deform the tungsten metal at ordinary temperatures. As remarked earlier, however, tungsten in this condition is malleable at elevated temperatures, and advantage is taken of this property to reduce the cross-section of the treated rod. It is of vital importance that the metal should be hot at the moment of deformation, and the swaging process of mechanical hammering is ideally suited to such an operation.

The essential features of the swaging machine, consisting of alloy steel dies mounted in a rotating shaft, are shown diagrammatically in Figure 2. The two halves of the die move rapidly back and forth in a radial direction as they revolve and thus hammer any material that may be inserted between them. After heating to some 1500°C. in the hydrogen atmosphere of a muffle furnace, the tungsten rod is withdrawn by hand tongs and pushed between the halves of the revolving die. Centrifugal force pulls apart the revolving die blocks, but they are intermittently driven together by impacts from an enclosing ring of rollers which strike the outer ends of the blocks. Since the bearing surface of the die

is short and the tungsten bar is constantly moved forward the time of contact between die and rod is of short duration, and the tungsten is always hot at the point of deformation. Several rods are heated and passed through the first die which is then replaced by a smaller die, and the operation is repeated. Each reduction in diameter increases the length of the rod by some fifteen per cent. and after the length has reached about four feet the rod is pulled through the swager by rollers that grip the forward end as it emerges from the dies.

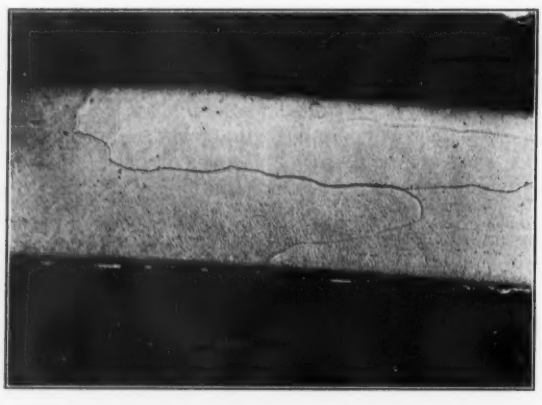

FIGURE 4.—"NON-SAG" STRUCTURE IN TUNGSTEN FILAMENT WIRE. × 300

As a result of this hammering the tungsten grains are elongated and a fibrous structure is developed as seen in the photomicrograph of Figure 3. This change in structure is accompanied by increasing toughness in the metal at temperatures below that of swaging. At the finish of the swaging process the diameter of the rod has been reduced to about 0.150 inch, and the final temperature of swaging is in the neighborhood of 900°C. Reduction in diameter is now continued by drawing the heated wire through dies of cemented tungsten carbide and finally through diamond dies at diameters less than 0.010 inch. Heat is applied to the wire and die throughout the drawing process, but the temperatures of final drawing operations are relatively low.

Except at the start of swaging the working temperatures lie below the recrystallization temperature of tungsten metal. Consequently, the process may scarcely be described as one of "hot working" in the strictest sense of that term. When a tungsten wire which has been made ductile by working is heated to a temperature of 1500°C. or above the fibrous metal recrystallizes and the wire again becomes brittle at room temperature as was the treated bar prior to working.

In most of the incandescent lamps today the filament is in the form of a coil which results in a considerable increase in efficiency over the former straight filament type. In order, however, to maintain such efficiency the coil must keep its shape (and not spread as shown in the slide). In other words, the filament wire must possess sufficient rigidity at a temperature of some 2500°C. to resist deforming or "sagging" under its own weight.

This property, known in lamp circles as "sag resistance," is a function of the grain structure developed within the wire when first reheated to a temperature above that required to recrystallize the fibrous structure in the worked condition. In studying the problem of "sag resistance" Jeffries found that at temperatures above some 1500°C. the stiffness of the wire increased as the grain size. A structure composed of very large grains is therefore desirable in a coiled filament which is to maintain the spacing of its turns during the life of the lamp. Such a structure is now shown in Figure 4, and in Figure 5 a contrasting structure is observed which is characteristic of a wire having relatively low sag resistance. A method of insuring the large-grained sag-resisting structure was discovered by Dr. Aladar Pacz and consists in introducing fractional percentages of alkali silicates into the tungsten oxide before reduction. During the subsequent high temperature treatments these additions are lost except for a residue which may be detected only by the spectroscope. However, they leave their mark behind in the ultimate grain structure of the wire by some mechanism as yet

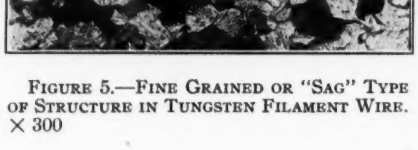

FIGURE 5.—FINE GRAINED OR "SAG" TYPE OF STRUCTURE IN TUNGSTEN FILAMENT WIRE. × 300

unexplained. A routine test is made to determine this vital sag-resisting property in wire of current production before coiling. The wire is formed as a hairpin loop and after leveling to a horizontal position is burned at a fixed temperature for a given period of time after which its droop is measured.

I have mentioned a few of the many instances wherein tungsten behaves as a metal of extremes. It has a value to civilization extremely large in proportion to the small amount in pounds used as lamp filaments. This, however, is sufficient to save the people of the United States alone some three billions of dollars each year as compared with the expenditures which would be required to produce the same level of illumination with carbon filament lamps. Its value in high-speed steel, in the radio industry, and in the X-ray tube is great and impossible to appraise in terms of dollars, for a small amount of tungsten in some applications gives results that no amount of other metal can give.

HIGH SCHOOL NOTES

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Bulkeley High School, Hartford, Connecticut

The CONSUMER ASPECT *of* CHEMISTRY TEACHING[2]

ELBERT C. WEAVER[1]

Bulkeley High School, Hartford, Connecticut

Consumer interest is commanding increasing attention today. Evidence of this interest is reflected in more emphasis on the practical or functional side of chemistry in secondary schools and decreased stress on the more formal aspects of chemistry.

Early textbooks stressed applications of chemistry (1806). Later the academic trend predominated (1880–90). In modern times increased emphasis is again consumer-ward because (1) many modern products need interpretation, (2) they need intelligent consumers, and (3) they rely on advertising to create a demand. Industries are coöperating with educational institutions, but advertising agencies for general goods are lagging in accurate representation of the products they would sell.

A modern course in chemistry uses consumer interest for motivation, but should not neglect fundamental chemical principles.

✦ ✦ ✦ ✦ ✦ ✦

THE rise of the coöperative movement; the success of consumer-interest bureaus; the success of publications such as their bulletins and "1,000,000,000 Guinea-Pigs" which emanate from their activities; new food and drug laws, designed to protect consumers; and a consumer-conscious attitude on the part of producers—all these are evidences of a phenomenon of our times, namely, a general consumer interest.

This growth of consumer-centered activities is reflected in a renewed emphasis on the practical side of chemistry. More strongly than ever today comes the demand that high-school chemistry should be functional and not something set apart from the reality by the covers of a book. Secondary-school pupils ask continually, "What's it good for?" and teachers and recent textbooks go to great pains to supply an answer.

In tracing back the consumer theme in chemistry textbooks, one finds that chemistry was introduced into the curriculum of the secondary schools at an early date. In those days before industrial specialization the home was by necessity self-sufficient. Ashes were leached for lye which later found its way into soap. Meat was home-cured, vinegar home-made, also beverages, candles, cheese, medicines, insecticides, and in some cases dyes, molasses, and salt. The practical aspects of chemistry in the schools of the day may be seen from the title page of "Plain Discourses on the Laws or Properties of Matter, containing the Elements or Principles of Modern Chemistry with more particular Details of those practical Parts of the Science most interesting to Mankind, and connected with Domestic Affairs, Addressed to all American promoters of useful knowledge." This book was written by Thomas Ewell, M.D., of Virginia, and appropriately dedicated to the great democrat, Thomas Jefferson, in 1806.

The "Chemical Instructor," fourth edition, was brought out in 1833 by Eaton, with this interesting preface which reveals that then, as today, a conflict of methods in presenting chemistry was possible.

> "It is a curious fact, that most of our learned professors in the modern sciences seem inclined to keep them aloof from ordinary citizens. They seem to view them as too elevated for any but the initiated *savans*.
>
> " 'You cheapen these sciences,' says my learned correspondent, 'by making them familiar things; felt and handled by the merchant and the blacksmith.'
>
> "Chemistry must then be embarrassed by chlorides, iodides, bromides, etc., to obscure them and to discourage the *vulgis communis*. Mere mites in science, of no practical use, clothed in mystic language, must be made to occupy a large space in our books, to intimidate learners, lest the Farmer and Mechanic, and even women, should trespass on the sacred *arcana* of the learned professors. My seventeen years of hard labor are to be set down *minus;* because my efforts have been directed to a bad purpose—that of making the farmer, the mechanic, the cook, and the spinster intelligent companions."

No information is at hand to reveal the success or failure of this effort.

A random examination of several textbooks written in each decade of the last and the present century reveals this general tendency. The consumer aspect is apparently a strong feature in some early textbooks.

[1] Presented before the Division of Chemical Education at the ninety-seventh meeting of the A. C. S., Baltimore, Md., April 5, 1939.

[2] Present address: Polytechnic High School, Long Beach, Cal.

It drops to a minimum at about 1880 or 1890. Changes in the life of the people and in the character of the secondary school may account in part for the rigidly academic character of textbooks of the eighties. The "machine age" of specialization has started, and industry is no longer centered at homes but in factories. The academy has become almost exclusively college preparatory, and chemistry courses are given for the sake of chemistry as a preface to more chemistry.

Not all books were uniform then, however, any more than they are today. A textbook dated 1887 and written by Dr. Ira Remsen contains over twice as much practical material as some of its contemporaries. But consumer interest had its sharp limitations in those days. Professor Remsen's book mentions bread, but no butter.

In the course of the years a change of emphasis on consumable objects is noticeable. Flints for fire-lighting in early books are replaced by a description of matches. Then as their use becomes popular, safety matches are also described. Today both types of matches and the cerium-steel flints for cigar-lighters may be included.

The modern situation presents a third aspect of the problem. The secondary-school chemistry course is a terminal course for most of the pupils. Further, the multitude of consumer goods made by chemical methods is overwhelming. Adequate knowledge of the commercially available synthetic plastics, for example, is already beyond the scope of most chemistry teachers. This leads to another feature of modern consumer goods, namely, they need interpretation and they depend upon advertising to create a demand. Directions aren't necessary with an old-fashioned bar of soap. Everyone knows how to use that. Directions are necessary, however, for effective use of soap flakes, soap granules, water softeners, or soap substitutes, and advertising is needed to sell them in a competitive market.

The need for an intelligent public to consume its goods has led industries to join forces with educators. This coöperation may be witnessed by a readiness on the part of industrial leaders to allow school children to visit their plants where practicable, by providing non-advertising moving pictures for classroom use at cost of transportation, and in supplying samples, charts, pamphlets, and other materials suitable for classroom use at low cost or gratis.

Industries are also carrying on independent educational campaigns. In order to understand the need for ethyl fluid in gasoline, for example, the public must be educated to the lore of compression ratio and its effect. These campaigns may develop horizontal organizations such as those represented by the several institutes, the U. S. Beet Sugar Association, International Tin Research, or the Ethyl Corporation which, for example, cuts across all dealers in gasoline who use their product; vertical organizations, represented by the Research Laboratories Section of the General Motors Corporation; and independent organizations such as the Aluminum Company of America and many other companies which now make goods unfamiliar to people a generation ago.

These educational campaigns should be capitalized by chemistry teachers. Contacts with these agencies, visits to shops, samples from industries, and modern textbooks crowded with the practical side of chemistry all furnish strong motivation to pupils. Such activities help take chemistry out of a textbook and articulate it with daily life.

The chemistry teacher battling against the advertising agency and its misrepresentations which are supported by the most subtle psychological approach is a classroom spectacle which our pupils must enjoy. Recently, newspapers in a well-known chain sent marked copies of a nationally known magazine to all the teachers in their localities. The editor of the magazine in person wrote a preface to an excellent series of articles which glorified modern advertising. In this editorial he makes the remarkable statement, "... more, the efforts of self-discipline in a modern business had gone far to eliminate such tricky deceitfulness altogether from modern advertising." Since much of modern advertising is for products which use the resources of science, and advertisement writers do not hesitate to state "Science says. . .," let us examine the next three advertisements which follow the editor's statement.

We object, as chemistry teachers, to having our pupils make incomplete comparisons in the classroom. We do not give credit to them for knowing much about chemistry if they say, for example, ammonia is lighter, or that substances burn better in oxygen. Yet the first advertisement, one for a popular low-priced automobile, contains five of these meaningless and incomplete comparisons. The car is lower in price, bigger, longer in wheelbase, but the reader is not told whether the comparison is with the cars of competitors, former models of the same car, bicycles, freight cars, or a combination of them.

The second advertisement would have you take something into the stomach because it "helps Nature counteract acidity"—a new angle on the stomach's function, according to most information.

The last member of this trio would sell a certain brand of whiskey to its readers because "It'll warm you up." The magazine in question appeared during cold weather, but all during the previous summer we were informed by advertisements to keep cool with another brand of this versatile beverage. Happy is the chemistry teacher who can discern where pure informing stops and propaganda begins. Some newspapers employ a science editor to check the accuracy of their science news. There is a definite and obvious need for the same supervision of advertising which bears the name science.

A danger exists in presenting a course in a reference frame of marketable products and calling it chemistry. Chemistry consists of much more than a description of

isolated substances and materials. We fail in our duty to the pupils who come to us unless we can show them the principles of the science, applications of the scientific method of problem solving, and, more important in these days of subsidized indolence, a wholesome zest for, and appreciation of, the hard work that goes into science—a work which finds its security in adventure and personal initiative, rather than in legislation.

In consumer education the school can conduct a constructive piece of work. One-fourth of the business of the country is chemical in nature. This sets a challenge to teachers to keep informed of new developments, to interpret changes, and to sift facts from falsehood. Educational campaigns conducted by industrial interests should be used to further classroom activity while a scientific and critical attitude is maintained. In undertaking consumer education as a part of the chemistry course, chemistry teachers have at once a large responsibility and an opportunity to revive popular interest in the study of chemistry.

ANNOUNCEMENTS

SPECIAL CHEMISTRY COURSES FOR TEACHERS AT WESTERN RESERVE UNIVERSITY SUMMER SESSION, 1940

THE Department of Chemistry of Western Reserve University, realizing the need for help and inspiration for the high-school teacher of chemistry, is offering in the summer session for 1940, beginning June 17, in coöperation with the Division of Chemical Education of the American Chemical Society, two special graduate courses, looking to the solution of two important problems of teaching chemistry in secondary schools.

The first course, called "Work Shop in Chemistry" attacks the important problem of the minimum and optimum essentials in high-school chemistry, which the average normal pupil can accomplish.

The second course has in mind the ultra-bright student, who chafes at the slow pace of the average student and demands and should have extra curricular chemical activity. This course, styled "Demonstrations and Projects in High School Chemistry," is a seminar course to develop experiments and projects suitable for extra laboratory work for the brighter student and for science programs and assemblies.

These courses are offered in the afternoons, giving plenty of time for study and for observation in the various summer high-school sessions in chemistry in Cleveland in the morning.

Arrangements will be made for visiting teachers to visit various schools in operation in Cleveland and other points of interest.

Teachers of chemistry, who take these courses, will have the opportunity to attend a series of sixteen lectures on current national and international issues in the Summer Institute on Current Affairs. The lecture series will have as its central theme "The Major Issues of 1940." The lecturers invited to participate in the series are chosen because of noteworthy contributions to the problems.

For further information on these courses offered in the Department of Chemistry, write the Summer Session, Western Reserve University, Cleveland, Ohio.—M. V. McGILL.

ANNUAL MEETING OF THE AMERICAN SCIENCE TEACHERS ASSOCIATION

The American Science Teachers Association held its seventh annual meeting in Columbus, Ohio, on December 27 and 28, 1939.

The program included papers on synthetic rubber, the anti-scorbutic vitamin, junior academies, the role played by the Brooklyn Botanical Gardens in cooperation with the public schools, and the problems invaluable in placing science in general education at the college level. A five-year science-art project in the form of a history of science in a mural painting was on exhibit and described. The retiring president, Dr. Walter B. Cannon, of the A. A. A. S. delivered the luncheon address.

Officers elected for the year 1940 are:

President—HARRY A. CUNNINGHAM, Kent State University, Kent, Ohio.

First Vice-President—HOMER W. LESOURD, Milton Academy, Milton, Massachusetts.

Second Vice-President—RALPH K. WATKINS, University of Missouri, Columbia, Missouri.

Secretary—DEBORAH M. RUSSELL, State Teachers College, Framingham, Massachusetts.

Treasurer—LOUIS J. MITCHELL, Dansville High School, Dansville, New York.

M. V. McGILL

R. L. EBEL REPRESENTS DIVISION OF CHEMICAL EDUCATION

The Chairman of the Division of Chemical Education has appointed Mr. Robert L. Ebel, Edison Institute, Dearborn, Michigan, as permanent member of the National Committee on Science Teaching, representing the Division of Chemical Education.—M. V. McGILL.

RECENT BOOKS

INORGANIC QUANTITATIVE ANALYSIS. *Harold A. Fales*, Ph.D., Professor of Chemistry at Columbia University, and *Frederic Kenny*, Ph.D., Professor of Chemistry at St. Francis College, Brooklyn. Second Edition. D. Appleton-Century Co., Inc., New York, 1939. xiii + 713 pp. 132 figs. 14 × 22 cm. $4.00.

In revising this book, which so successfully pioneered the elementary teaching of quantitative analysis from the theoretical viewpoint, the authors have added and interpolated much new and valuable material, without making many appreciable changes in the wording or general organization of the original text. The result is a truly contemporary book, embodying most of the special virtues and some of the defects of the older edition. The admirable explanatory spirit of the original has been conserved and even increased, and the reader is often pleased by passages of unusually clear and elegant exposition. In only a few places does one find any marked incoherence or lack of conclusiveness, and the failure to correct such barbarous inventions as "we impliedly know" (top of page 165) is a defect which seems to be noticeable chiefly because of contrast.

In the selection of the laboratory exercises, the authors again have maintained the policy of the earlier book: some very common determinations (such as the titration of acetic acid) are omitted, but the discussions and explanations are so clear and practical that any fairly intelligent student might well succeed in making his own plans for such analyses. In some places, however, one could wish for a larger number of practical examples of the theoretical material; thus the highly detailed and uniquely valuable chapter on electrodeposition is followed by the simple, well-studied example of copper (under various conditions), and a second laboratory example (lead) is found only after some searching. In the same spirit the eminently practical chapter on photometric methods contains only one exercise, the Nessler method for ammonia.

Most of the chapters dealing with theory have been expanded in the direction of more detail, rather than increasing depth of treatment. Thus the structural formulas of numerous indicators are given exactly as before, without mention of the tautomeric forms responsible for the changes of color; the reason for the variation in breadth of color range of different indicators is hinted only very faintly. The reviewer might willingly agree that these are matters of curiosity not closely related to practical analytical work, but the same is true of the formulas themselves. Again, in the discussion of oxidation-reduction equilibria there is a considerable tendency toward the use of "bare" ion formulas, such as Sn^{++++} and Ti^{++++}, instead of the more realistic $SnCl_6^{--}$ and TiO^{++}, and so forth; here also the difference is not practical, but the theory lacks precision.

In some few places, the new edition has retained an arbitrary tone not conducive to the best pedagogical effect. The original propaganda against the use of the concept of normality remains in full force, and continues to be effective because of the absence of any clear explanation of ways of avoiding ambiguity. The conventions employed in electrochemistry are traditional, and there is not even a footnote reference to the newer system of Lewis and Randall; inasmuch as this system is used in at least one of the very best reference books on electrode potentials, the omission seems unfortunate. It might be pointed out also that the discussion of oxidation-reduction equilibria is unnecessarily complicated, because of the persistent separation of the electrode potentials throughout every calculation. It seems that an arrival at the use of expressions of the form

$$E = E_1 - E_2 + \frac{RT}{nF} \ln Q$$

(where E_1 and E_2 are the separate electrode potentials and Q is the ionic quotient for the whole reaction) would have simplified the calculations, and also would have given a far clearer picture of the relation to equilibrium constants.

In spite of these and other minor defects, this book is far better, both as an elementary textbook and as a reference-source for more advanced material, than most of the commonly used textbooks of quantitative analysis. It seems likely that it will be chosen by many careful teachers of the subject. It is one of the very few books, usable for elementary instruction, which gives many references to the original literature; it is almost unique in the use which it makes of ionic activities (although this use is limited, perhaps wisely); it may well be the only textbook of quantitative analysis which includes a really up-to-date summary of the use of organic precipitants. On the whole, it is to be highly recommended, especially for advanced work, and it should hold a favorable position for a long time to come.

ANTON B. BURG
THE UNIVERSITY OF SOUTHERN CALIFORNIA
LOS ANGELES, CALIFORNIA

BIOLOGICAL OXIDATION. *C. Oppenheimer* and *K. G. Stern*, with the collaboration of *W. Roman*. Nordeman Publishing Company, Inc., New York, 1939. 317 pp. 19 × 26.5 cm. $8.25.

The book contains the following chapter headings: "Introduction" (five pages); *General Part* consisting of "Theories of Oxido-Reduction" (forty-eight pages); "Phenomena of Oxidative Catalysis" (seventy-three pages); *Special Part* consisting of "The Enzyme System" (eleven pages); "General Biological Significance of Desmolysis" (thirteen pages); "Cell Respiration" (seventeen pages). There is an extensive "Bibliography" (thirty-three pages), and a "Subject Index" but there is no "Author Index."

According to the Preface this monograph had been developed from Dr. Oppenheimer's chapter on biological oxidation in his "Supplement" to "Die Fermente." "The text had been made less dependent on other expositions. In doing so it was understood, however, that for fuller information the reader should still be referred to the 'main work' by Oppenheimer (1926), the Supplement, and to the original publications."

In the first ("General") part of the book the theories dealing with biological oxidations and reductions are excellently dealt with. In the second ("Special") part, however, there appear a number of incorrect and confusing statements.

The formation of an intermediary enzyme-substrate compound between monoethyl hydrogen peroxide and liver catalase as described by Stern is quoted (page 176). The unstable intermediary compound is supposed to have the properties postulated by the theory of Henry and Michaelis for an intermediary enzyme-substrate compound. Keilin and Hartree (*Proc. Roy. Soc.*, **B121**, 173 (1936)), however, found that ethylhydrogen peroxide is not a substrate for catalase since weak solutions of ethylhydrogen peroxide are not attacked by catalase solutions if free from other hematin compounds.

Doubt is cast (page 207) as to the possibility of obtaining pure synthetic cocarboxylase by the method of Weijlard and Tauber (*J. Am. Chem. Soc.*, **60**, 2263 (1938)); whereas it is well known that pure cocarboxylase has been manufactured for some time on a commercial scale by this process.

On page 210 the existence of ascorbic acid oxidase is questioned. Later (page 267) one reads, "The existence of ascorbic acid oxidase as a specific enzyme is more or less generally accepted." The results of course speak for a specific enzyme (GRAUBARD, *Enzymologia*, **5**, 332 (1939)). The statement (page 267) that only *l*-ascorbic acid is attacked by this enzyme is incorrect. *d*-Ascorbic acid is also oxidized but at a much slower rate (ROSENBERG, *Skand. Arch. Physiol.*, **76**, 119 (1937) and others).

It is stated (page 210) that ascorbic acid is probably the coenzyme of esterase. Pantschenko-Jurewicz and Kraut (*Biochem. Z.*, **285**, 407 (1936)), however, found that ascorbic acid itself cannot be the coenzyme for esterase since on the addition

of ascorbic acid to coenzyme free esterase there is only a very slight restoration of the initial esterase activity.

On page 228 one reads the following contradiction, "It is probable that there is no separate phosphorylase as a synthesizing enzyme, as distinct from phosphatase. Phosphorylation is probably the back reaction catalyzed by phosphatase." In the next paragraph, however, it is stated that "Euler and Adler obtained monophosphorylase in partially purified form." Of course there is sufficient evidence at hand, as found in various laboratories, that specific phosphorylases (phosphateses) do exist.

No mention is made in this monograph of the important new discovery of dioxymaleic oxidase by Banga and Szent-Györgyi (*Z. Physiol. Chem.*, **255**, 57 (1938); *Nature*, **142**, 874 (1938)).

In spite of the occasional inaccuracies the book contains a good review of the literature. It will prove a useful addition to the biological chemist's library.

HENRY TAUBER

CHICAGO, ILLINOIS

MODERN ASPECTS OF INORGANIC CHEMISTRY. *H. J. Emeléus*, D.Sc., and *J. S. Anderson*, Ph.D., Imperial College of Science and Technology, London, D. Van Nostrand Company, Inc. New York, 1939. xi + 536 pp. 14 × 21.5 cm. $9.00 (supplied for text use at a lower figure).

This book begins where most texts on inorganic chemistry leave off. It is intended to furnish information on "developments which have taken place in inorganic chemistry during the last two decades or so, and to relate those developments to the science as a whole." Material which is readily accessible in the standard textbooks has been omitted, except as it is needed to introduce the more recent knowledge or more advanced concepts. The book is, in reality, a discussion of special topics in inorganic chemistry. As such, it departs from the usual outline based upon the Periodic Table, and presents the subject from a new point of view.

Most of the recent advances in inorganic chemistry have been made through the aid of physical chemistry, and this is reflected in these pages. The authors have done remarkably well in interpreting this knowledge in simple terms, so there are no special prerequisites for an easy understanding of most of the topics presented.

The book is primarily intended for advanced students, research workers, and teachers. Teachers of advanced courses will wish to consider it as a textbook; teachers of elementary chemistry will also find it a valuable book to own. It can be used to supplement the material given in the textbook, and as a reference in answering the multitudinous questions which even elementary students ask about atomic structure, isotopes, newly discovered elements, the structure of alloys, radioactivity, and other topics which are frequently mentioned in the popular scientific journals. The better and more interested students may be referred directly to Emeléus and Anderson, as they can read and understand most of it without difficulty.

The chapter headings are as follows: Atomic Structure and the Periodic System, Atomic Weights and Isotopes, Structure of Molecules of Inorganic Compounds, Coördination Compounds and Inorganic Stereochemistry, Polyacids and Silicates, Hydrogen and the Hydrides, Free Radicals of Short Life, Non-Metallic Oxides and Related Substances, Recent Chemistry of the Non-Metals, Peroxides and Peracids, Recent Chemistry of the Metals, Metallic Carbonyls, Nitrosyls and Related Compounds, Intermetallic and Interstitial Compounds, Reactions in Liquid Ammonia and Liquid Sulfur Dioxide, Radioactivity and Atomic Disintegration.

MODERN ASPECTS OF INORGANIC CHEMISTRY deserves a wide acceptance, not only because it presents material which is not readily accessible in other books, but because of its clarity and excellence of organization.

JOHN C. BAILAR, JR.

UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

LABORATORY EXERCISES IN GENERAL CHEMISTRY. *James F. Norris*, Massachusetts Institute of Technology and *Kenneth L. Mark*, Simmons College. Second Edition. McGraw-Hill Book Company, Inc., New York City. 1939. xiii + 574 pp. 16 figs. 14 × 21 cm. $2.00.

This book is designed to accompany the new edition of INORGANIC CHEMISTRY FOR COLLEGES by Norris and Young. The order in which the experiments is given is somewhat different than in the first edition of the manual, and several new experiments have been added to illustrate topics not previously discussed. The book is a large one, having one hundred sixty-five experiments, so that the teacher may select as many as he needs. A wide variety of experiments is offered; some of these, of course, are well known, but a pleasingly large number are entirely new.

Each experiment is preceded by a discussion outlining the principles involved. The laboratory directions are clearly written, and in great detail, so accidents and unsatisfactory results should be reduced to a minimum. The right hand pages of the book are left blank for the students' notes, which are to be written largely in the form of answers to the numbered questions which appear in the discussion and directions.

Professors Norris and Mark have produced an interesting, well written manual, which deserves careful examination by all teachers of elementary chemistry.

JOHN C. BAILAR, JR.

UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

EARLY FIRE-MAKING METHODS AND DEVICES. *Warren N. Watson*. Gibson Brothers, Inc., Washington, D. C., 1939. 71 pp. 15.5 × 23.5 cm. $1.50 cloth bound, $1.00 paper bound.

ESSENTIALS OF PHYSIOLOGICAL CHEMISTRY. *Arthur K. Anderson*. Second Edition. John Wiley and Sons, Inc., New York City, 1939. x + 323 pp. 15 × 23 cm. $2.75.

In 1935, Dr. Anderson's first edition of this book appeared. In this edition he attempts to bring the subject matter more up-to-date and for the purposes of the text he has done a very creditable job.

The appearance of the book from the outside will not give students for which it is especially written that inferiority feeling which comes over so many when they first see the thick biochemistry textbooks which are being published today. The book is a thin one, well printed and indexed, and contains but three hundred two pages of subject material. The author makes it plain that his book is not supposed to be a comprehensive one in the subject and that it is not written for students of dentistry and medicine. In his preface to the first edition Anderson writes, "Although designed for students of human nutrition, it is hoped that this book will prove of value in more general courses in animal biochemistry such as are given to pre-medical, agricultural, bacteriological, and other biological students."

Upon opening the book to determine the order of subject matter presentation, I find it much more to my liking than many of the newer arrangements now used. When the book has been mastered well, a student will have the bare essentials of the subject in mind in logical sequence, physical chemistry concerned, carbohydrates, fats, proteins, food compositions, enzyme action, digestion and intestinal putrefaction, absorption, carbohydrate, fat and protein metabolism, energy metabolism, composition of tissues, blood, urine, hormones, and vitamins.

The physical chemistry concerned is well explained, and especially hydrogen-ion concentration. The proof of structure of carbohydrate molecules is scanty, it probably being assumed that such discussions belong in a course in organic chemistry. Fats and oils are discussed thoroughly enough for such a book, but the protein chapter is, in the opinion of the reviewer, too incomplete. Biological oxidations and reductions are discussed in three pages, and consequently only the surface is scratched. The composition of tissues is brief but a good addition to the first edition. The remainder of the book "hits the high spots"

with no effort made to discuss any one phase of the subject thoroughly. Considering the author's objectives, the book is complete enough and has its place in undergraduate teaching of the subject.

SIDNEY S. NEGUS

MEDICAL COLLEGE OF VIRGINIA
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GENERAL CHEMISTRY, THEORETICAL AND DESCRIPTIVE. *Thomas P. McCutcheon*, University of Pennsylvania, *Harry Seltz* and *J. C. Warner*, Carnegie Institute of Technology. Third Edition. D. Van Nostrand Co., Inc., New York City, 1939. xiii + 685 pp. 74 figs. 13 × 21.5 cm. $3.75 net.

The third edition of this well-known text has been almost completely rewritten. Recent developments have been included and many sections have been materially expanded. It represents a sixty-five per cent. increase in size as compared with the first edition. The authors have continued their plan of segregating theoretical discussion from descriptive chemistry. As explained in the preface to the first edition this arrangement is used for the purpose of giving the student a concise summary of both fact and theory which is free from diverting and irrelevant matter, while at the same time it gives the instructor a "maximum opportunity to inspire and interest his students by injecting his own method and personality into the course." As an aid in utilizing this unique feature of the book the authors have included a "Syllabus of Weekly Assignments" which presumably gives an idea of the sequence followed by the authors in their own classes. This syllabus gives a series of topics arranged for thirty-two weeks of instruction, with intermingling of descriptive material and theory. In this manner a logical development of the subject is assured. The order of topics in the syllabus should be easily adjustable, but the reviewer fears that this process will present some difficulties.

Part I covering the theories of chemistry contains nineteen chapters and occupies three hundred forty-three pages. The discussions begin with the simple concepts, such as the divisions of natural science, the classification and structure of matter, and the laws of chemical combination. There are chapters on the states of matter, atomic and molecular weights, valence, energy relations, atomic theory, solutions, electrolytes, velocity of reactions, equilibrium, standard solutions, solubility product, activity coefficient, electrochemistry, and colloids. In comparing the present book with previous editions the following additions are to be noted: an additional chapter on atomic theory and its use in explaining chemical and physical phenomena; the Debye-Hückel theory and its applications; Brønsted theory of acids and bases; and chemical kinetics. The authors have been unhampered by the usual intermingling of theory and description so it has been possible for them to give a more thorough treatise for these topics than can be found in most textbooks. Many of the chapters include a brief, but choice list of references for additional reading. There is also a new list of problems.

Part II, Descriptive Chemistry, contains twenty-seven chapters and three hundred fourteen pages. As in previous editions the authors have described the non-metals in a group and then followed with a summary of the metals using the order suggested by the Periodic Table. The most notable addition is the inclusion of two new chapters on the compounds of carbon and the applications of organic chemistry in modern life.

The authors have taken unusual pains to give accurate values for the physical constants used. One of the most helpful features of the book is the frequent and effective use of graphs, tables, and diagrams. The illustrations are neat and effective. The photographs are taken from the splendid collection of Edgar Fahs Smith, to whom the book is dedicated. There is no appendix. On the inside front cover is a list of 1939 atomic weights and on the inside back cover is a copy of the Periodic Table. The type is clear and the mechanical features of the book have been carefully attended to. No mention is made of a laboratory manual.

The book is planned for use in first-year college chemistry for students who have had previous experience in the physical sciences. It is an excellent book for teachers who prefer to arrange their own sequence of topics. Many students will find difficulty with parts of the theoretical discussion, and it is likely that some teachers will find it necessary to omit certain sections entirely. The continuous discussion of theory makes the book a splendid reference book, giving a connected view of the fundamental theories of the science. Some of the space devoted to applications, especially of the metals, is brief in comparison with the space devoted to theoretical considerations, but this tendency is almost universal among modern textbooks in elementary chemistry.

B. S. HOPKINS

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LABORATORY COURSE IN GENERAL CHEMISTRY. *Gardner L. Carter*, Professor of Chemistry, University of Virginia, and *James W. Cole*, Assistant Professor of Chemistry, University of Virginia. Second Edition. D. Van Nostrand, Inc., New York City, 1939. x + 225 pp. 12 figs. 14 × 17 cm. $2.00.

This laboratory manual is designed to meet the requirements of the usual college freshman course. To those familiar with the first edition it is sufficient to say that the entire book has been rewritten, certain sections have been expanded, and a chapter on qualitative analysis added.

For the stranger it must be explained that the authors have attempted to present the laboratory work in a more pleasing fashion than in the usual manual. In place of the familiar experiment headings we find the material grouped under general titles such as "Substitution Reactions of the Metals," "Double Decomposition Reactions among Acids, Bases, and Salts," and so forth. The usual experiments on manipulations are omitted, and the necessary instructions such as are required for bending glass tubes are inserted in small print at appropriate points. This gives the student an opportunity of carrying out reactions illustrating chemical change at his first laboratory period and avoids the danger of losing his interest while performing manipulative technic.

Beginning with Chapter XII the four succeeding chapters are headed as periodic system groups; however, with the exception of Mn and Cr, it is only the non-metals that are considered. Some few of the metals are mentioned in an earlier part of the book, but many receive attention only in the qualitative separations.

With the exception of titrations, pH measurements, and an industrial mineral problem practically no quantitative experiments are given. The usual experiments on molecular weight, valence, equivalent weight, conservation of mass, Boyle's Law, and Charles's Law are not included.

Ionization is considered from the Arrhenius standpoint. The term molecule in reference to strong electrolytes as NaCl and $NaNO_3$ is commonly used. Reactions of strong electrolytes such as that between NaCl and $AgNO_3$ are classed as double decomposition. Hydrochloric acid and potassium chloride are listed as belonging to the same electronic type and ionizing in a similar fashion.

It seems unfortunate to use the separation of iron and cobalt salts with NH_4OH in the presence of NH_4Cl as an illustration of the common ion effect. The familiar complex ion formation and subsequent oxidation of the cobalt must confuse the issue.

An excellent group of exercises is placed at the end of each chapter. Some of these require laboratory experimentation, while others are of the usual type.

The book is well written and amply illustrates that it is the product of many years of thought and experience. In general the directions are adequate and the student should find no difficulty in following the procedures.

C. E. WHITE

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COLLEGE PARK, MARYLAND

THE WAR GASES, CHEMISTRY AND ANALYSIS. *Dr. Mario Sartori*, chemist of the Italian Chemical Warfare Service. Preface by *Professor G. Bargellini* of Rome University. Translated from the second enlarged edition by *L. W. Morrison*, B.Sc., A.I.C. D. Van Nostrand Co., Inc., New York City, 1939. xii + 360 pp. 20 figs. 15 tables. 15 × 23 cm. $7.50 net.

This is a book on the munitions of chemical warfare, not on chemical warfare in general. The author says in his preface, "It is with the confidence of being able to contribute modestly to a wider knowledge of the war gases and in the hope of satisfying requests for a book which should contain all the purely chemical data, at present published in the various manuals of chemical warfare in fragmentary or summary form, that I have collected in this volume all the best and most recent work published up to the present on the chemistry of the war gases." The author has done satisfactorily what he set out to do.

Part I comprising thirty-two pages is general, considering the physiopatholoigcal, physical, and chemical properties which a substance must have to be of use as a war gas. These requirements are illustrated by many tables of toxicities, vapor pressures and other properties of actual war gases. The relation between chemical structure and aggressive action is discussed with reference to halogen, sulfur and arsenic atoms and cyan, nitro and other groups and the effects that these have in various structures on the effectiveness of the compounds. War gases are classified in several different ways, according to their physical properties, their tactical uses, or chemical properties.

Part II, comprising two hundred ninety pages takes up the war gases in detail, devoting a chapter to each of the following groups: halogens, divalent carbon compounds, acyl halogen compounds, halogenated ethers, halogenated esters, halogenated aromatics, aldehydes, halogenated ketones, halogenated nitro compounds, cyanogen compounds, sulfur compounds, and arsenic compounds. In each group each compound is described, the amount of space given to it depending upon its importance. For each there is a statement of its discovery and applications and then of the reactions by which it can be prepared. The laboratory preparation is given, followed by the industrial manufacture, its physical properties, chemical reactions, and physiological effects. Each statement is backed by a reference to the literature. There are about fifteen hundred references to articles by about six hundred authors.

The book is recommended to those who want to know what gases were used, how they were made, and what their effects are.

E. EMMET REID

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GERMAN-ENGLISH SCIENCE DICTIONARY FOR STUDENTS IN THE AGRICULTURAL, BIOLOGICAL, AND PHYSICAL SCIENCES. *Louis De Vries*, Professor of Modern Languages, Iowa State College. McGraw-Hill Book Co., Inc., New York City, 1939. x + 473 pp. 12.5 × 18 cm. $3.00.

The introduction of this book points out that "Research within the various departments of science has gradually developed during these years into complicated interdepartmental problems. No entomological vocabulary, for example, can today dissociate itself from the many aspects of biology in general; even the physical sciences are embraced. Terms must be included covering not only entomology and the sciences into which it enters, such as embryology, cytology, physiology, morphology, genetics, ecology, but also chemistry, physics, botany, and medicine, all of which enter into modern treatises on insects." The purpose of this dictionary is, therefore, to fill the need of many students and investigators in the fields of science for a dictionary that does not attempt to limit itself to just one of these fields. The reviewer's experience for nearly the past ten years as a member of the committee on German reading knowledge examinations for advanced degrees has fully confirmed the need for such a dictionary. Most particularly students in the biological sciences have shown their need for such a dictionary as judged by their performance on these reading knowledge examinations.

The dictionary has been compiled with the aid of thirty-four collaborators in various fields of science. Their names are given. The author fully realizes that the 48,000 entries in the book do not make it a complete dictionary covering all these fields but has attempted to make the best selection possible to cover all of them and yet have a handy sized dictionary that is very usable and not complicated by too great a multiplicity of translations for each word. A useful list of five pages of abbreviations is placed at the end of the dictionary.

This dictionary cannot replace such specialized German-English dictionaries for chemists as Patterson's with its 42,000 entries and more complete list of translations for each word, but it can be a very useful and helpful additional source for the chemist interested in problems that overlap into other fields not chemical, and this is the condition with many problems today. The reviewer has found the dictionary useful in abstracting work for *Chemical Abstracts* in chemical fields that overlap into mycology and believes that this dictionary will be especially useful to the biologist and to the chemist whose work reaches into the biological field.

The book is well manufactured and bound and the printing clear.

ODEN E. SHEPPARD

MONTANA STATE COLLEGE
BOZEMAN, MONTANA

EXPERIMENTS IN PHYSICAL CHEMISTRY. *Herschel Hunt.* Revised Edition. John S. Swift Company, Cincinnati, Ohio, 1939. v + 95 pp. 67 figs. 21 × 27 cm. $1.90.

This is a planographed manual containing directions for performing forty-five experiments. As the author states in the preface, the object is to provide an outline to guide the student in the laboratory and not a text on technic. The experiments are designed to be used with any class book. Data sheets and graph paper are included so that the records may be kept in the book or a separate report written up outside of the laboratory. The first five pages are devoted to glass-blowing technic and good diagrams are given to illustrate the methods of performing various operations. Each experiment is set up under the headings: information; questions; apparatus and chemicals; procedure. The information is sometimes presented too briefly to be of full value and in some cases the questions go beyond the scope of the experiments, but the procedures are well written. The drawings are good, and many cuts were made from actual pictures of apparatus.

A. A. VERNON

NORTHEASTERN UNIVERSITY
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VISUAL OUTLINE OF GENERAL CHEMISTRY. *Ralph E. Dunbar*, Ph.D., Professor of Chemistry, North Dakota Agricultural College. Longmans, Green and Co., New York City, 1939. iv + 348 pp. 32 figs. 13.5 × 21 cm. $0.75.

The author has attempted to summarize in brief statements all of the information given in general chemistry. Twenty-one of the better known general texts are listed in the bibliography along with forty books on other phases of chemistry. The statements are grouped in forty-eight chapters, arranged in about the same order as they would appear in a text. For each substance, the outline is, approximately: Introduction, Occurrence, Preparation (laboratory, commercial), Physical Properties, Chemical Properties, Uses, Analytical Tests. The information includes some obsolete material and methods and very rarely omits an important item. For instance, the method for preparing I_2 from $NaIO_3$, $2NaIO_3 + 5NaHSO_3 \longrightarrow 3NaHSO_4 + 2Na_2SO_4 + I_2 + H_2O$, used in Chile is not mentioned. The total amount of information is enormous, but it is condensed so much that this book should be used for the purpose for which it was written: outline, review, organization of information, and a supplementary text but never as a principal source for an understanding of chemistry. Many of the statements would be utterly meaningless if not amplified by a teacher or a text.

Structural formulas are shown for organic compounds. Model

problems of all kinds met by freshmen in chemistry are solved, usually by substitution in appropriate formulas. Chemical equations are given to illustrate each principle or process as it is stated or described. In most features the review is more nearly up-to-date than the freshman texts. For instance, under Artificial Radioactivity, twenty artificially radioactive elements are named. Some incongruities must necessarily be included if review material for twenty-one texts is to be furnished. The classical definitions for acid and base appear, but $H_3{}^+O$ also is mentioned; "Complete Ionization (Debye and Hückel)" and "Degree of Ionization of an Electrolyte" are adjacent paragraphs, and the calculations are for strong electrolytes. Nearly all equations are molecular equations. Some misstatements have slipped in. On page 1 appears, "Boiling point is the transition point of liquid to gas" and on page 3 "Displacement is when...."

These and the other similar unavoidable errors which creep into first printings will undoubtedly be corrected in the next printing. The appendix includes useful tables and a glossary of more than two hundred chemical terms frequently misunderstood by freshmen. In the opinion of the reviewer this book will be an aid to good students for organization and review and a temptation to lazy students to learn groups of words which they hope will serve as a substitute for knowledge at examinations.

F. E. BROWN

IOWA STATE COLLEGE
AMES, IOWA

CHEMICAL SPECTROSCOPY. *Wallace R. Brode*, Professor of Chemistry in the Ohio State University. John Wiley and Sons, Inc., New York City, 1939. xi + 495 pp. 293 figs. 15 × 23 cm. $5.00.

The purpose of the book as stated by the author in the Introduction is "to supply spectroscopic information to chemical workers, as well as to serve as a textbook for a course in chemical spectroscopy." It would seem from an examination of the volume that the author has attempted to prepare a book which would refer to all of the spectroscopic information of interest to a chemist and would contain a working manual with directions for carrying out a number of spectroscopic procedures useful to chemical analysts.

Methods for qualitative and quantitative analyses by emission and by absorption spectra are described. Tables of the wave-lengths of the principal spectral lines of the elements and spectrum charts are included in the book, and these are extensive enough to be adequate for much of the analytical work that a chemist would likely be interested in doing. In addition, the book contains directions for twelve laboratory experiments designed for the training of students in spectroscopic technic and analytical procedures. A brief chapter on the theory and description of color is included and, finally, a discussion of the theory and practice of photography and suggestions for the arrangement and equipment of a spectrographic laboratory.

Because of the rapid increase during recent years in the use by chemists, chemical engineers, metallurgists, and manufacturers of spectroscopic methods and data in research, analytical, and developmental work and in the control of the production of chemicals, metallic alloys, and other products, the appearance of this book is timely. It will be a valuable aid to those who wish to enter the field of applied spectroscopy as a profession and to those who want to learn what can be done by spectroscopic methods and how spectroscopic data may be interpreted. The wide range of applicability of spectroscopy to problems in chemistry is indicated and the attempt is made in brief discussions of the theories of atomic and molecular structure and atomic and molecular spectra to show how one may obtain from spectroscopic data such important information as the constitution of a sample of material, the structure and dimensions of molecules, the strengths of bonds between atoms and atomic groups in molecules, the heats of dissociation of molecules, and so forth.

The number of topics discussed or mentioned in the book is very large, and the reader becomes conscious of a conflict between the desirability of making the book a complete compendium of spectroscopic information and the necessity to limit its size. As a result, some of the topics are treated so briefly as to make their appreciation and understanding from a study of this book alone quite impossible. Some subjects as, for example, the structure of the atom, are discussed in such elementary terms in order to save space that the ideas are hardly in conformity with the present views of experts in the field. Even the directions for analytical procedures, particularly those for quantitative analysis by emission spectra, are briefer than one could wish, and the correlation between the fundamental theories and the analytical procedures is weak because of the limitations imposed by the size of the book. It will be necessary both for the student and the analyst to consult other works and original papers to get a full understanding of the subjects discussed and to get detailed working directions for analyses. An adequate bibliography is given in the book for this purpose.

The book is profusely illustrated, and the illustrations will be found to be valuable as aids to an understanding of the subjects discussed and as guides for work along similar lines. The pictures of instruments available for spectroscopic work and the references to them and to their manufacturers will be helpful to those who wish to purchase such equipment. The listing on the spectrum charts of the principal lines of many elements in their approximate positions in the spectrum will be found to be a great convenience to spectroscopic analysts.

O. S. DUFFENDACK

UNIVERSITY OF MICHIGAN
ANN ARBOR, MICHIGAN

THIRD DIGEST OF INVESTIGATIONS IN THE TEACHING OF SCIENCE. *Francis D. Curtis*, Ph.D., Professor of Secondary Education and of the Teaching of Science, University of Michigan. P. Blakiston's Son & Co., Philadelphia, 1939. xviii + 419 pp. 14 × 19 cm. $3.50.

As the title implies, this is the third volume in a series. The first was published in 1926, the second in 1931. The current volume together with the preceding ones furnish a record of the efforts of science teachers to use research methods in the study of their teaching problems. The record as given in these three volumes may be regarded as practically complete through 1937.

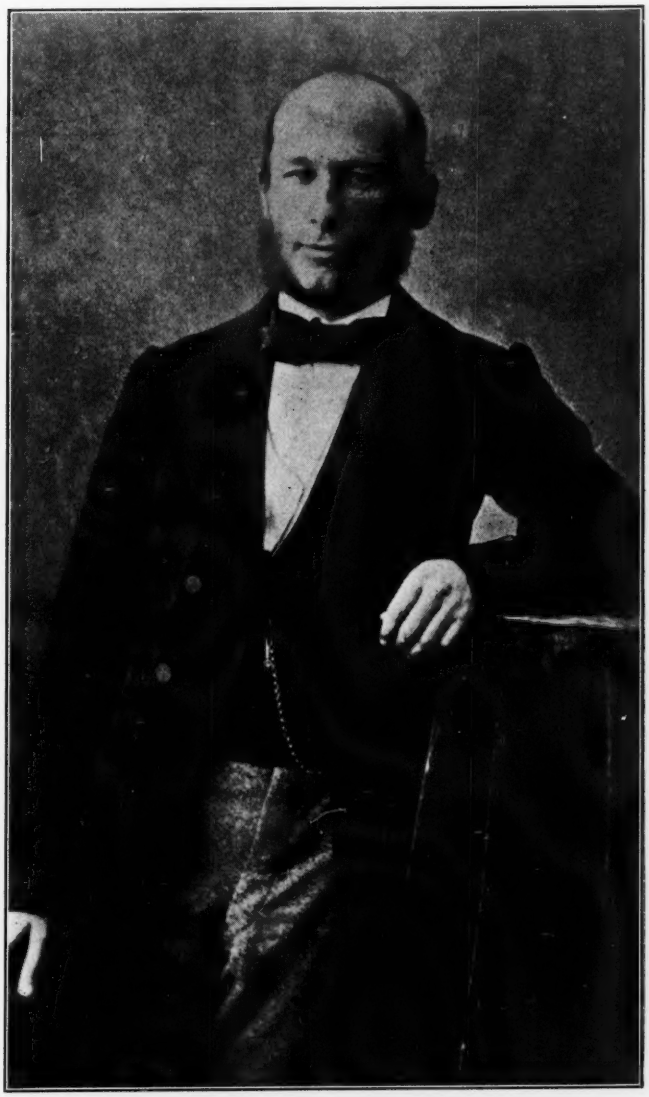
As in the Second Digest, the members of the National Association for Research in Science Teaching coöperated with the author in selecting the investigations to be digested. The technics employed allowed the inclusion of some few highly opinionated reports which might not have been included as investigations by a more rigid criterion. However, the merits of the method employed in making the selection outweigh its demerits.

The grouping of investigations, together with the number of digested studies in each group, will indicate something of the scope of the work and possibly give a hint as to the extent of professional activity on the part of teachers. There are five dealing with teaching science in the elementary school; ten with teaching general science; seven with teaching biology; eleven with teaching physics; six with teaching chemistry; forty with science teaching in secondary schools, without reference to a particular subject; and fifteen dealing with some phase of college teaching, mostly with survey courses and with problems of teacher education. The book reviews ninety-four investigations. Of these thirty-five are dissertations offered for degrees of Doctor of Philosophy in fifteen universities.

It is the intention of the author and publisher "to issue a fourth volume a few years hence, bringing the presentation of important research work in this field of education again up-to-date." Professor Curtis is doing a valued service for students of science teaching and of secondary education. He may be assured that his fourth and succeeding volumes in this series will be eagerly welcomed.

S. R. POWERS

TEACHERS COLLEGE
NEW YORK CITY



A. M. BUTLEROV (1828–1886)

Butlerov was a contemporary of August Kekulé. He was educated at the University of Kazan. He was professor there from 1858 to 1868, and, afterwards, professor at the University of St. Petersburg. His greatest contribution to organic chemistry was the discovery of the tertiary alcohols. His textbook on organic chemistry, based on August Kekulé's work, had a very far-reaching influence.

(Contributed by E. Berl, Carnegie Institute of Technology)

EDITOR'S OUTLOOK

EDITORIAL APPOINTMENT. At the recent Cincinnati meeting of the American Chemical Society, the Board of Publication of the Division of Chemical Education appointed Dr. Norris W. Rakestraw of Brown University, Providence, Rhode Island, to succeed the present editor. Dr. Rakestraw has assumed responsibility for the preparation of the September number. In the meantime, manuscripts intended for future publication should be submitted directly to him.

Since it is evident that there is no immediate prospect of any material increase in the space available to the JOURNAL it appears desirable to cut down the present backlog of accepted manuscripts to a number that assures only a comfortable working margin over the printer's schedule—that is, to the point where most manuscripts accepted will be assured of publication within three to four months of their acceptance. This task the Board of Publication has undertaken in cooperation with Dr. Rakestraw.

The task is not an easy one, and may even prove painful. The retiring editor sympathizes with the Board's members and bespeaks for them the consideration and forbearance of contributors who may feel the bite of the axe.

Such regrets as the present editor feels at the necessity of loosening (though he hopes not of severing) the bonds of many pleasant attachments formed in this work are to some extent assuaged by the confidence that the welfare of the publication itself is to be placed in such able hands. Dr. Rakestraw's long period of service to the Division, his breadth of acquaintance, his popularity both within and beyond the Division, and his recognized intelligence and judgment are highly reassuring in this respect. Furthermore, in addition to the personal loyalties he will bring to his new work, he will inherit as editor of the JOURNAL the faithful, loyal service of a host of excellent advisers, helpers, and well-wishers.

To these latter the retiring editor feels that he owes a great debt of gratitude—one that he can scarcely repay, but that he can at least acknowledge. They will, he knows, continue to serve the JOURNAL and to assist its editor as they have in the past.

ALEXANDER MIKHAĬLOVICH BUTLEROV

HENRY M. LEICESTER

College of Physicians and Surgeons, San Francisco, California

AMONG the leaders of chemistry in the mid-nineteenth century was Alexander Butlerov, who contributed much of both theoretical and experimental nature to the fundamentals of organic chemistry. However, his important work has been largely forgotten, and, although he ranks with Kolbe and Kekulé as one of the founders of structural theory, even his name is unfamiliar to most modern chemists.

In order to understand Butlerov and his achievements, it is necessary to know something of the conditions under which he lived and worked. In about the year 1840, the center of chemical research in Russia was to be found at the small provincial University of Kazan, founded only thirty-six years before, in the east central part of the country. That this was true was due to the presence of two men on the faculty, Karl Karlovich Klaus and Nikolaĭ Nikolaevich Zinin.

Klaus, the professor of chemistry, was both a botanist and a chemist, but he was chiefly known for his work on the platinum metals and for the discovery of ruthenium.[1] He was an ardent follower of Berzelius and held to the latter's dualistic theory long after it had been abandoned by almost the entire chemical world. Klaus was a tireless and enthusiastic worker, but his outlook was somewhat limited. He was practically self-educated and though he visited many parts of Russia in the course of his botanical researches, he did not travel abroad until nearly the end of his life.

Zinin, the professor of technology, was a very different type of man, and a far broader one. He had begun his career as a mathematician, but he was soon attracted to organic chemistry, and he devoted his life to this subject. He travelled extensively in western Europe and worked for some time in the laboratory of Liebig, where he absorbed to the full the spirit of research. His most famous work,[2] published in 1843, was the discovery of the reduction of aromatic nitro compounds to amines, which led to the first synthesis of aniline and naphthylamine. His broad experience and active scientific work kept Zinin abreast of the latest developments in chemistry and, as a result, he did not always see eye to eye with the more conservative Klaus.

In spite of the excellent work of these two men, and of the high reputation which they held, the physical equipment of the Kazan laboratory was very poor. Before Klaus came to the university there was no laboratory at all. He converted as much room as possible into working space, but even in 1857, when V. V. Markovnikov was a student at Kazan, conditions were far from satisfactory. Markovnikov described the laboratory as consisting of one room containing two Dutch tile tables, a large stove, a sand bath, and several sorts of furnaces. Behind a low parti-

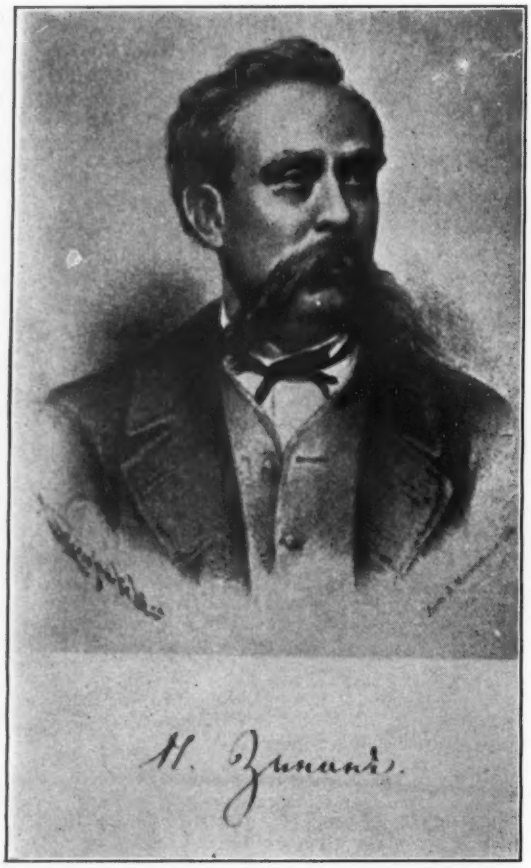
A. M. BUTLEROV

[1] According to Markovnikov (*6*), Klaus had the habit of stirring the solutions of the platinum metals in aqua regia with his fingers and determining the strength of the remaining acid by taste. A sketch of his life is given by Weeks (*8*).

[2] Of this work, Hofmann later said, "If Zinin had done nothing more than to convert nitrobenzene into aniline, even then his name should be inscribed in golden letters in the history of chemistry" (*5*).

tion the old laboratory servant washed the apparatus. No gas was available. All the lecture experiments were prepared in the room, which was so crowded that the students carrying on research were forced to work in the embrasures of the windows.

In addition to these physical difficulties, the intellectual atmosphere was not of the best. The Russians of this period lived more or less apart from the currents



N. N. ZININ

of scientific thought which were arousing the rest of Europe. A man like Zinin was the exception; for most Russians the situation was that described by Markovnikov when he said, "Between Russia and Europe there existed a strong, high wall, and only a few succeeded in breaking through it. We remained as if in quarantine, strongly protected from the infecting breath of Europe" (*6*).

Such were the conditions and the atmosphere into which, in 1844, came the young student, Alexander Mikhaïlovich Butlerov. He was born on August 25, 1828 in the small town of Chistopol, not far from Kazan. His father was a retired lieutenant-colonel, a landlord of the district. As his mother died when he was only eleven days old, he spent his early years in the home of his maternal grandfather. He received most of his lower education in the Kazan Gymnasium, and proceeded directly from that institution to the University of Kazan.

He was interested in the natural sciences, and enrolled in this division of the university, but almost from the first he devoted himself largely to chemistry. In this way he came almost at once under the influence of Klaus. Zinin was not directly connected with the purely chemical courses, but a student with the great interest and activity which Butlerov displayed could not long remain unaware of the excellent work which was going on in Zinin's laboratory. Klaus and Zinin, in their turn, were attracted by the brilliancy of the young student.

Butlerov began to work with Klaus on the preparation of antimony, but Zinin's activities soon drew his interest. He himself later said, "A sixteen-year-old student, a novice, I was naturally attracted by the external side of chemistry, and I was especially interested in the beautiful red plates of azobenzene, the yellow needles of azoxybenzene, and the glittering scales of benzidine. Zinin returned my interest and quickly acquainted me with the progress of his work and the different benzoins and naphthalene compounds with which he afterwards worked. Little by little I began to work by preference under the guidance of Zinin, which was not limited to his own studies. He also felt an interest in the repetition of outside experiments. Although he entrusted these to his students, he himself also carried out most of them. Thus, along with him, we performed a number of known experiments, preparing uric acid and indigo, undertaking the dry distillation of dragon's blood, and obtaining malic, gallic, formic, oxalic, and other acids. From these different experiments his students obtained almost automatically an acquaintance with the different branches of organic chemistry, and this acquaintance came of itself and was clothed, so to speak, in flesh and blood because the substances from the various branches of nature passed before our eyes, and one could not be lazy when one worked along with the professor" (*3*).

Butlerov was soon inspired by this work to independent studies. He goes on to say, "How active an interest in facts was thus aroused is clear from this, that, not satisfied with experiments at the university, I made preparations at home. Solemnly I would bring to the laboratory the objects which I had prepared at home, caffeine, isatin, alloxanthine, and others. I frequently drew on myself the reproaches of those who lived in the house with me, since the nitric or sulfuric vapors drifting through the place did not please those who were not accustomed to a laboratory atmosphere" (*3*).

The activity and the stimulation which he found in these surroundings undoubtedly gave Butlerov a firm and lasting foundation in the field of organic chemistry, and one which underlay his later work. However,

unfortunately for him, in 1847 Zinin was called to the Medico-Surgical Institute in St. Petersburg, and Butlerov was left entirely under the guidance of Klaus. As a result, he was cut off from the new developments which were then occurring so rapidly in the west. For the next ten years he was left in an atmosphere of scientific conservatism, a backwater of progress.

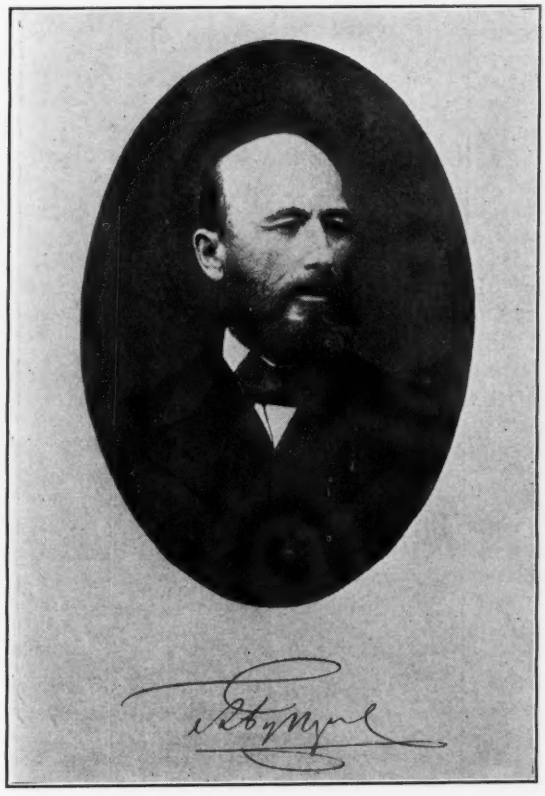
In 1849 Butlerov completed his work for the Candidate's degree with a thesis on the butterflies of the Ural-Volga region. The young man's abilities had so strongly impressed the Kazan faculty that they wished to keep him in the university. The only position available at the time was that of lecturer in physics and physical geography, and to this Butlerov was accordingly appointed. At the same time he was working on his Master's degree. He completed his thesis in 1851, at which time he received the degree.

This thesis was entitled "The Oxidation of Organic Compounds," and was a critical review and coördination of all the available literature on the subject. In his conclusion, Butlerov wrote the following prophetic words, "When we look back, we cannot avoid astonishment at the great steps made by organic chemistry in the short period of its existence. Its future, however, appears to be incomparably greater, and the time will finally come when the products of organic changes will be studied not only qualitatively, but quantitatively, and, little by little, we will expose and determine the true and exact laws of its compounds and understand their natural place in the chemical system. Then, chemists, knowing the properties and general conditions for the preparation of any compound, will be able to determine not only its composition, but also its other properties. This time can and must come for our science, and then, along with the work already available, what a field it will be for enthusiastic development" (*9*).

At the time Butlerov received his Master's degree, he was appointed adjunct in chemistry to assist Klaus. Shortly afterwards, in 1852, appeared his first published chemical paper, which concerned the action of osmic acid on a rather heterogeneous assortment of organic compounds. The results were not very conclusive, but they showed that the research instinct was awake in him.

In 1852 Klaus was called to Dorpat, and Butlerov was left to carry on much of the chemical work. At the same time he was engaged in research for his doctoral dissertation, which he completed in 1853. This thesis concerned the ethereal oil of a Russian plant and the isolation from it of a camphor-like substance. The thesis was approved by the professors of chemistry and mineralogy, but Savel'ev, the professor of physics, did not consider it satisfactory for the Doctor's degree. The Senate of Kazan University wished, therefore, to submit the thesis to some other university for a final decision, but there was no method by which this could properly be done. The matter was finally settled by permitting Butlerov to submit his dissertation to the University of Moscow, where it was approved. He was granted the degree of Doctor of Chemistry and Physics by that university in 1854.

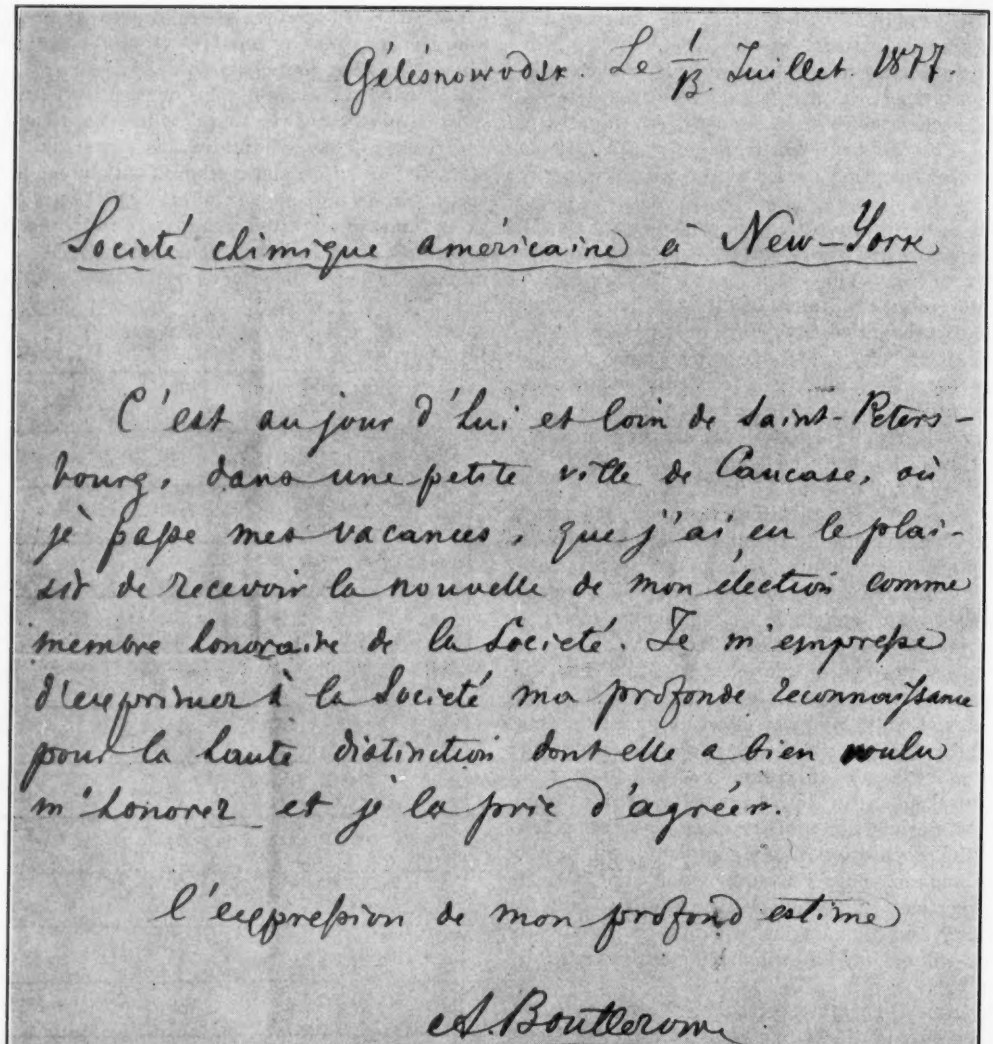
Following the receipt of his degree, Butlerov made a short trip to St. Petersburg, where he visited Zinin, who was actively continuing his researches and had attracted an enthusiastic group about him. This visit was an important step in arousing Butlerov from the sleepy and conservative atmosphere which prevailed in Kazan. Zinin had become an ardent convert to the unitary theory of Gerhardt and Laurent. He was the first Russian chemist to appreciate the significance of their work, and he explained it in detail to Butlerov,



A. M. BUTLEROV

presenting him also with copies of the "Méthode de Chimie" and the "Traité de Chimie Organique." Butlerov was excited by these works, and the shackling influence of Klaus began to fall away. Not for three more years, however, was he to become entirely free from the older ideas.

Butlerov now returned to Kazan as extraordinary professor of chemistry. For the next few years he devoted himself to a series of tentative and rather inconclusive researches. He studied reactions between weak mercuric chloride solutions and lime water, the action of phosphorus triiodide on mannitol, and the



Gélénowodsk. Le 1/13 Juillet 1877.

Société chimique américaine à New-York

C'est au jour d'hui et loin de Saint-Petersbourg, dans une petite ville de Caucase, où je passe mes vacances, que j'ai eu le plaisir de recevoir la nouvelle de mon election comme membre honoraire de la Société. Je m'empresse d'exprimer à la Société ma profonde reconnaissance pour la haute distinction dont elle a bien voulu m'honorer et je la prie d'agréer.

l'expression de mon profond estime

A. Boutlerow

(*Courtesy of Edgar Fahs Smith Memorial Collection, University of Pennsylvania*)

THE LETTER IN WHICH BUTLEROV ACCEPTS HONORARY MEMBERSHIP IN THE AMERICAN CHEMICAL SOCIETY

behavior of turpentine under various conditions. During this time he also published several papers of a horticultural and zoölogical nature. In 1858 he was raised to the rank of ordinary professor.

At this time he had the reputation of being one of the best professors in the university. Markovnikov, who entered Kazan in 1857, was led to study chemistry by the reputation of Butlerov. He described his instructor as follows, "Besides the internal content of Butlerov's lectures and his ability of expression, he fully had the appearance of a professor. Before us stood a young and lively lecturer with manners as animated and polished as his words. That natural reserve which we noticed in him in the auditorium vanished entirely when he was in the laboratory. Here he was not only a good and kind teacher, always ready to listen to a

question and give an answer to each of his students, but he was also a comrade to each of the workers. He not only listened to and told anecdotes, but his sincere and ringing laugh usually included all those around him. When we worked in the laboratory, we felt it a home, perfectly free. However, this did not prevent each from doing his work properly" (*6*).

Nevertheless, Butlerov himself realized to the full the results of his ten years of scientific isolation. In his own words, he "remained no more than a good student, possessing a rather full collection of facts, but still completely limited in scientific outlook and in critical reaction to affairs." The time had now come when he was able to take the step which turned him, as he said, "from a student to a scholar" (*3*).

In June, 1857, Butlerov set out on a trip through western Europe which lasted until August, 1858. He had a perfect command of French and German, and had long been developing his abilities upon the fundamental training which he had received from Zinin. Thus, he was perhaps better equipped to take advantage of the new ideas which he encountered than those who lived where these were developing, and in whom familiarity bred indifference.

Butlerov went first to Berlin and the laboratory of Mitscherlich. Here, for the first time in his experience, he saw the use of gas in a chemical laboratory. All the experiments at Kazan had been carried out with the aid of spirit lamps or coal furnaces, and the difficulties of running an organic analysis under these conditions were formidable. During the rest of his journey, Butlerov was constantly on the watch for novelties and improvements which he could take back to Kazan with him.

From Berlin he travelled through Germany, visiting most of the chemical centers. He spent some time in Heidelberg, where Kekulé was a privat dozent. Kekulé was on the point of publishing his famous paper on "The Chemical Nature of Carbon" (April, 1858), in which the idea of valence was first expressed, and Butlerov was greatly interested and impressed by this theory. The friendship which then began between the two men had a great influence on the later work of Butlerov.

After leaving Heidelberg, Butlerov travelled through Switzerland and Italy, and in December, 1857, he reached Paris, where he remained until May, 1858, with the exception of a ten-day visit to London to see the laboratories of Hofmann and Williamson. At this time, Paris was full of outstanding chemists, not the least of whom was Adolph Wurtz at the École de Médicine. Butlerov worked in his laboratory during most of his stay in Paris. He studied the preparation of methylene iodide from sodium ethylate and iodine, and its reaction with silver acetate to form the acetate of methylene glycol. This was the first connected and successful piece of work in the chemical field which Butlerov had carried out, and his enthusiasm was greatly aroused by it. While in Paris, Butlerov met Dumas, Berthelot, St. Claire Deville, Balard, and Chevreul. He also attended the meetings of a group of young and active chemists which later developed into the French Chemical Society.

When he had completed his work in Paris, Butlerov returned to Heidelberg, where he attended the lectures of Bunsen and Kekulé. The latter interested him, as he said, "by the clearness and precision of presentation, and by the originality and novelty of some of the ideas introduced by the lecturer in the theoretical part of organic chemistry" (*9*).

Following this visit, Butlerov continued his trip through Germany, and at Munich he inspected the gas plant which Pettenkoffer had installed there. In July he returned to St. Petersburg, and then at last to Kazan. Here he immediately began to introduce the improvements he had observed abroad. He installed a small plant to manufacture gas, and, for reasons of economy of space, he located the storage tank under the floor of the laboratory. This made the work of the students much easier, but gave at least some of them the feeling that they were working above the crater of a volcano.

In his theoretical ideas at this time Butlerov was a supporter of the unitary and type theories of Gerhardt and Laurent, but he was familiar with the work of both Kekulé and Couper, which had appeared at about the same time, and he recognized the need for modifying the current theories as new facts appeared. Thus, at the end of 1858, he said, "Although type formulas can explain only double decompositions, and not the internal construction of a substance, yet it does not follow from this that the constitution can never be known, and I think even Gerhardt himself, although he shows the impossibility of explaining the molecular structure by the present formulas, does not think the resolution of this structure will forever remain impossible. New discoveries will permit us to go farther in our theoretical ideas. . . . . Experimental study will give us the basis for chemical theory for the molecular forces which we call chemical affinity. However, since affinity serves as a reason not only for chemical changes, but also for determining the grouping of elementary atoms in complex molecules, then this affinity should be studied not only at the time of molecular movement, but also in a state of equilibrium" (*6*). Here we see that Butlerov was already well on the way to an expression of the structural theory.

With his theoretical ideas already so firmly based, Butlerov began the activity in the laboratory which lasted the rest of his life. Naturally enough, he began his work by continuing the studies on which he had been busy in Paris. His attempts to isolate methylene glycol itself failed, but he showed the impossibility of the existence of free methylene, and the formation of higher hydrocarbons where it might have been expected to occur. In the course of this work he obtained the polymer of formaldehyde which he called dioxymethylene. His study of the reaction of this compound with ammonia led to the first isolation of hexamethylene tetramine. He also treated the polymer with lime

water and obtained a sugar-like substance, the first example of the synthesis of a carbohydrate from relatively simple substances.

In 1861, Butlerov again travelled in western Europe, visiting a number of German and French laboratories and renewing his acquaintance with Kekulé, who was now at Ghent. He then attended a scientific congress at Speyer. Here he was struck by the lack of agreement among the various scientists present on any uniform theory to explain the facts of organic chemistry. However, for the three preceding years, he had been developing his own ideas during the lectures at Kazan. He was convinced that there was an underlying basis for all the apparently contradictory theories of the German chemists, and he felt that this basis was to be found in the actual constitution of the compounds themselves. The results of his thinking were embodied in a paper which he read to the congress. It was entitled "The Chemical Structure of Compounds." This was the first use in organic chemistry of the term "chemical structure," and so it is to Butlerov that we owe this expressive phrase (*1*). In this paper he showed the difficulties which arose from the application of the unitary theory alone and advocated a partial return to the older electrochemical ideas. The truth lay somewhere between the ideas of Gerhardt and Laurent and those of Berzelius. In this point of view it is possible to recognize the result of his early training under both Klaus and Zinin. He expressed his ideas clearly when he said, "A new opinion usually widens what went before; it is to be preferred because it considers the facts from a new angle and shows those analogies which had previously remained unnoticed, but this does not exclude the correctness of the older ideas when they have gone to the limit of the facts which lay before them. Unfortunately, this is often forgotten by the proponents of a new theory or belief" (*6*). This paper was the first clear and outspoken statement of the new structural theory and the ideas expressed in it required practically no revision later.

When Butlerov returned to Kazan, he made a report to the University Senate in which he summed up his experiences and gave a remarkably keen and penetrating analysis of the character and work of the leading European chemists whom he had met on his travels. Indicating the state of his own ideas, he wrote in this report, "None of the ideas which I found in western Europe seemed especially new to me. Laying aside here misplaced false modesty, I can say that these ideas and conclusions have been quite familiar in recent years in the Kazan laboratory, and they have not been considered especially original. They were developed in the general course of the work and were introduced in part into the lectures" (*7*).

Shortly before his second western journey, Butlerov had been appointed Rector of Kazan University, but he did not want a position which interfered with his chemical activities, and he therefore asked to be relieved of these duties. However, the University Senate, convinced of his ability, elected him Rector again in 1862. He served for only five months, and in April, 1863, he again resigned the position and devoted himself to the research which was already producing important results. Nevertheless, he continued to have great influence in the university, and his advice and experience were frequently sought. After he had left Kazan, it was a common remark among the faculty when trouble arose, "If Butlerov had been here, this would not have happened."

His first publications after his return to Kazan were of a theoretical nature. He pointed out that the apparently conflicting theories of Kekulé and Kolbe had in reality much in common, and he went on in several papers to develop and popularize the structural theory. Very soon he began to support his theoretical ideas by a series of brilliant laboratory studies. In 1864 he published the results of a study of the action of zinc dimethyl on phosgene and described the mixture of alcohols which was obtained. He then studied the reaction in which acetyl chloride replaced phosgene and obtained a new alcohol which he showed to be *tert.*-butyl alcohol. This was the first representative of the class of tertiary alcohols to be prepared. Kolbe had predicted that such compounds should exist, but it remained for Butlerov to discover them and explain them in far simpler terms than had Kolbe. Butlerov continued to work on the tertiary alcohols for some time, improving the methods of preparation, studying their oxidation, and isolating many derivatives. In the course of this work he discovered the isomeric butanes and butenes. While he was carrying out these major investigations, Butlerov also conducted a number of less spectacular, but by no means unimportant studies.

During this period Butlerov also wrote his "Introduction to the Full Study of Organic Chemistry" which first appeared in its Russian edition in 1864. This was one of the first texts to be based entirely on the structural theory, for even Kekulé's textbook had been based on the ideas of Gerhardt and so was not a strictly modern text. Butlerov's book appeared in its German translation in 1867, and Markovnikov, who was then studying with Kolbe, tells of the great impression which it made. Kekulé's benzene theory appeared shortly before the German edition of Butlerov's book, and some questions of priority arose. The situation was summed up by Markovnikov as follows, "Kekulé, and especially Couper, actually gave the first explanation of the atomicity of carbon and its accumulation in complex compounds, but this was still far from the theory which related not only to carbon compounds, but to all chemical substances in general, and we actually saw that Kekulé himself gave only second-rate value to his original communication. The services of Butlerov are that he gave full value to this hypothesis and developed it into the whole structural system" (*6*).

In August, 1867, Butlerov made a third trip abroad which lasted until June, 1868. While on this journey, he received word that he had been appointed ordinary professor of chemistry at the University of St. Peters-

burg. His selection for this important position was largely due to Mendeléeff, who had been greatly impressed by his work on chemical structure. Butlerov returned first to Kazan and settled his affairs there. When he left, he was elected an honorary member of the University of Kazan. He gave his first lecture at St. Petersburg on January 23, 1869.

His abilities were quickly recognized, and he soon attained the front rank in the scientific circles of the capital, where he remained until his death. He became the acknowledged leader of a school of chemists from which came almost all of the chief Russian organic chemists of the next generation (*4*). In this connection he impressed all his associates by his kindliness, sincerity, perseverance, and open frankness. He was a member, and for a time, president, of the St. Petersburg Academy of Sciences, and he was elected an honorary member of the Russian and most of the foreign chemical societies. In 1876 he was one of the group of distinguished chemists chosen for honorary membership in the newly formed American Chemical Society, and the letter in which he accepted this distinction is still extant.

His outside interests were many and varied. He was much interested in the education of women, and for many years lectured for them in the higher chemical courses. He was an enthusiastic beekeeper, and became one of the leading Russian apiarists. In the later years of his life he became greatly interested in spiritualism, and a firm believer in it. On this ground he was the subject of rather widespread ridicule in Russia, but he did not permit this to sway him from his belief.

During the first few years after his arrival in St. Petersburg, Butlerov continued the work he had been carrying on at Kazan. In 1872 he turned to a new field, the synthesis and properties of trimethyl acetic acid, which he prepared by treating *tert.*-butyl iodide with mercurous cyanide and hydrolyzing the tertiary nitrile thus formed. These studies led him to investigate the structure of pinacolone, which he correctly interpreted. At the same time he continued his studies on unsaturated hydrocarbons and on the synthetic possibilities of the zinc alkyls.

In 1876 Butlerov presented a paper at Warsaw on diisobutylenes. This was published in the next year, and besides its excellent study of the reactions and polymerization mechanisms, it is noteworthy in that it contains the first clear statement of the theory of tautomerism (*2*). From *tert.*-butyl alcohol, Butlerov obtained by the action of sulfuric acid two isomeric diisobutylenes. He explained their formation by assuming an equilibrium between the two hydrocarbons, water, and the corresponding alcohols. He then went on to discuss the possible existence of an equilibrium between isomers, even in the absence of any reagent. He stated his idea thus, "In this case, in every study of the chemical structure of a substance, the molecule will always behave in two or more isomeric forms. It is clear that the chemical reactions of such a substance must occur in accordance with sometimes one, sometimes the other structure, depending on the reagent and on the experimental conditions." As a possible example, he suggested hydrocyanic acid. This work did not receive the consideration it deserved at the time, and it was not until the work of Laar in 1885 that the fact of tautomerism was generally recognized.

During the next few years, Butlerov continued his studies on isobutylene and began work on several naturally occurring compounds. At the same time, he began to consider the possibility that the molecular weight of a compound might not be constant. He spent his last years attempting to prove this, although he did not publish any experimental work on the subject.

In the spring of 1886, Butlerov's health began to fail. Although he was not considered seriously ill, he discontinued his work for the time and withdrew from the city. On August 5, 1886, he died suddenly at the early age of fifty-eight.

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Greater even than the greatest discovery is it to keep open the way to future discovery. This can only be done when the investigator freely dares, moved by an inner propulsion, to attack problems not because they give promise of immediate value to the human race, but because they make an irresistible appeal by reason of an inner beauty . . . . In short, there should be in research work a cultural character, an artistic quality, elements that give to painting, music, and poetry their high place in the life of man.—JOHN JACOB ABEL

The PROJECTION *of* CHEMICAL LECTURE EXPERIMENTS *onto the* SCREEN

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THE importance of lecture demonstrations is no longer questioned in natural science; the problem resolves to choosing the best demonstrations and the most effective method of presenting them to the students. The advantages of the usual lantern slide projector have been described recently by Conway.[1] A more convenient instrument for many purposes is the lecture-table projector of the type that projects a vertical beam, which is reflected by means of a mirror onto a screen above the instructor's head. The "Delineascope," an example of this type of projector, is illustrated in Figure 1. The holder for the lantern slide is horizontal so that various materials may be placed on the clear, glass-covered opening and projected.

With this projector transparent, semi-transparent or translucent materials and other materials which are meaningful in silhouette may be shown on the screen. The field covered is nearly three by three and one-half inches. The usable depth amounts to about five millimeters. However, if detail is not important throughout the depth, it is possible to project the image of a standard half-inch test-tube so that the color and the presence or absence of a precipitate will show on the screen. Tubes which are oval in cross-section, as used by the bacteriologists, may be obtained in either lime or pyrex glass and are particularly convenient for this type of demonstration. No special equipment is demanded for this work beyond that ordinarily found in the laboratory. A convenient type of dish for chemical experiments is the ordinary Petri dish, obtainable in diameters of two, three, and four inches.

The vertical projector is very convenient when one wishes to present the student a near view of some routine experiment. By placing a drop of material to be tested and a drop of indicator on the platform, the color change indicating alkalinity or acidity appears on the screen. The formation of a precipitate is of great importance in many chemical experiments. For instance, if one boils a test-tube of Fehling's solution, it can be held slantwise over the stage of the projector, the projection lens focused high enough to show it on the screen, and the student sees that its color is blue and is free from precipitate. On adding a bit of sugar and boiling again, the test-tube may be shown to contain a reddish brown precipitate proving the presence of a reducing sugar.

From routine demonstrations it is only a step to teaching some of the fundamentals of microchemistry. Instead of depending upon textbooks or demonstrations which could be shown only to a few students at a time, it is possible to make the demonstration with the projector before the entire class. Most of the methods of applying reagents[2] can be demonstrated on the projector if one uses half of a Petri dish and focuses the lantern sharply on the surface or on the materials used. The various procedures of filtration can be demonstrated. The material containing a precipitate may be

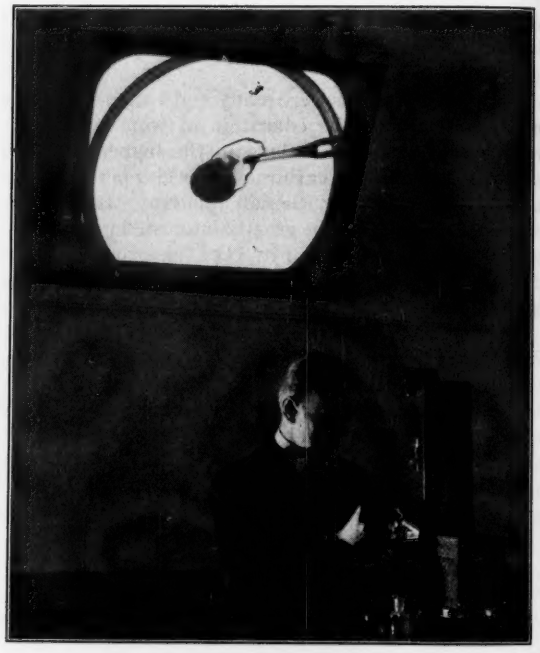

FIGURE 1.—MEDICINE DROPPER MICRO-FILTRATION DEMONSTRATED WITH A SPENCER MODEL B DELINEASCOPE

[1] CONWAY, "Transparent projections of lecture experiments," THIS JOURNAL, **16**, 314–16 (1939).

[2] CHAMOT AND MASON, "Handbook of chemical microscopy," John Wiley & Sons, Inc., New York City, **1931**, Vol. II, ix + 411 pp.

placed in a Petri dish, a strip of filter paper placed with one end in the solution and the dish tipped so that the liquid material runs through the strip and accumulates as a filtered drop at the other end (Figure 2). An interesting experiment for freshman chemistry is to mix a little tooth paste with water and filter it in this manner and then add a drop of silver nitrate to the clear filtrate. Immediate precipitation of silver chloride shows that the tooth paste contains salt. A filter stick may be made by placing filter paper in the open end of a medicine dropper (Figure 1).

It is possible if one makes a micro-burner by drawing out a medicine dropper to a fine point, to demonstrate micro sublimation on the stage of the lantern. The

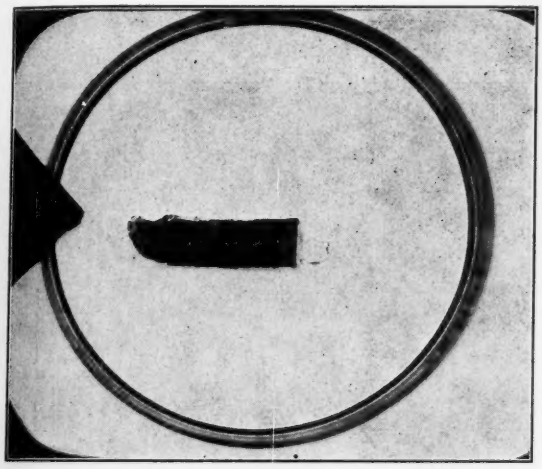

FIGURE 2.—FILTRATION WITH A STRIP OF PAPER

wide use of some types of micro reagents may be conveniently shown. An illustrative example would be the use of uranyl acetate as a test for sodium and potassium (Figure 3). Drops of sodium and potassium salts are placed in separate places in a Petri dish on the table of the projector, and then the uranyl acetate is added to each. In a short time the crystals are large enough to show on the screen the characteristic differences of the salts of these two metallic elements.

Many of the general principles may be shown conveniently. For instance, if one has a few Syracuse watch glasses, small stender dishes, or other small dishes filled with material of different refractive index, by immersing crystals in them one can show the effects of the index of refraction and how it is determined by the immersion method. The Becke line may be shown. Crystal forms can be shown if one chooses crystals which are not larger than about five millimeters in their greatest dimension. A broken crystal dropped into a saturated solution will repair itself before the eyes of a student and then grow appreciably during the lecture period. Water of crystallization may be demonstrated by placing a sodium sulfate crystal on the stage of the projector and allowing the heat from the lantern gradually to drive off the water.

Diffusion may be illustrated by taking a layer of about three millimeters of distilled water in a Petri dish and adding a drop of methylene blue or other dye

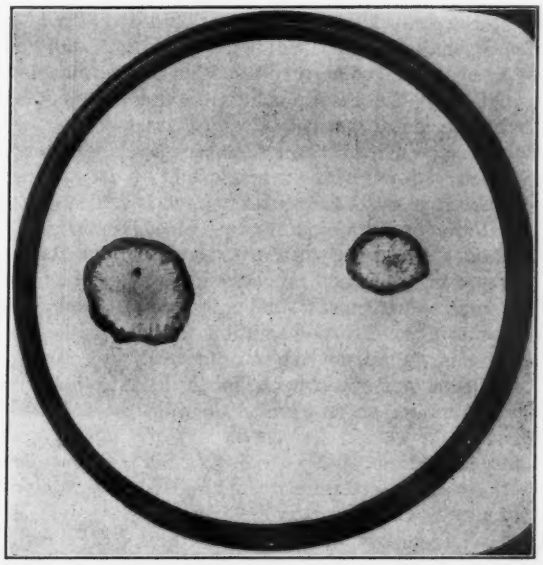

FIGURE 3.—NEEDLE CRYSTALS FROM POTASSIUM CONTRASTED WITH SMALL PYRAMIDAL CRYSTALS FROM SODIUM WITH URANYL ACETATE

in the center of the dish. The heat effects of convection currents from the heat of the lantern are interesting as well. Or, one may put a crystal of a colored chemical into the solution, or one may lay a test-tube slantwise across the field and then drop the colored crystal into the bottom of the test-tube. More elaborate types of diffusion may be shown by taking a thin layer of gelatin in a Petri dish and putting a drop of Congo red on one side and of eosine on the other. When the activity is too slow to show all in one lecture period, the dish may be kept and placed on the screen by means of the projector at successive lecture periods. It is not difficult to keep a quantitative record by turning the mirror of the projector so that it throws the image onto the blackboard or the lecture table within easy reach and tracing the outline of the stained region on a strip of paper. At the next lecture period, another student may add the outline and in that way a permanent record of progress is obtained.

Liesegang rings may be demonstrated by taking two milliliters of saturated potassium bichromate and one hundred milliliters of six per cent. gelatin. This is placed in a thin layer in the bottom of the Petri dish and after it is set, a drop of twenty-fifty per cent. silver nitrate is added to the center. The gradual formation of the precipitation rings shows clearly on the screen. Membrane formation may be demon-

strated by adding a drop or two of a potassium ferrocyanide solution to three per cent. copper sulfate. If a small amount of a strong sugar solution be added, then the difference from osmotic pressure may be demonstrated on the drops within the membrane.

A great many of the conventional experiments on surface tension may be demonstrated before the entire class at once. The commonest demonstration is to float a needle on distilled water and then sink the needle by adding some surface-active chemical such as a small amount of soap solution. One of the more interesting surface tension experiments is the well-known mercury amoeba. The crystallizing dish is half filled with ten per cent. nitric acid; a drop of mercury about a centimeter in diameter is added and a crystal of potassium bichromate is placed about a half-centimeter from the mercury. As soon as the bichromate dissolves and reaches the mercury the latter shows active movement similar to that of an amoeba. The color of the diffusing solution of bichromate shows clearly and the mercury shows effectively in silhouette. This spectacular experiment usually leads to considerable discussion among students after the lecture is over.

Determination of the hydrogen-ion concentration by means of a colorimetric method is easily demonstrated with the projector. A piece of glass such as a lantern-slide cover glass or the bottom of a Petri dish is coated with a very thin coating of vaseline. Then drops of buffer solution may be placed on this and a drop of indicator added to each. The drops stand up and may be seen on the screen-like colored glass beads.[3] A drop of the unknown is placed beside the series and a drop of indicator added. The comparisons are then made with the colors.

The swelling of gelatin may be demonstrated in buffer solution. The gelatin may be cut into discs with the aid of a cork borer, or a convenient source of pieces of the same size is the caps of some of the smaller gelatin capsules sold by the druggist. If the buffers are placed in small dishes it is possible to show several of them on the screen at one time. Otherwise, they may be shown successively. This experiment may also be made semi-quantitative by having the student keep a record of the amount of swelling of the capsule at the different hydrogen-ion concentrations.

Many experiments may be made with various colloids by using a thin layer of the colloid in a suitable dish. Mutual precipitation of one colloid by one of opposite charge may be readily demonstrated, or the colloid may be precipitated by placing two electrodes in the solution and passing direct current through. The effects of acids and bases on oil-water emulsions are readily demonstrated. Emulsifying agents and detergents can be illustrated in this manner. Colloidal gliadin is useful for many experiments and is readily made in the laboratory by taking an alcohol extract of flour and pouring it into distilled water to give a white milky colloid of positive charge which is stable and is useful for colloidal experiments. The effect of charge on staining is demonstrated by using semi-transparent or transparent materials. The formation of lakes may also be shown.

Electrochemical effects may be demonstrated readily with the vertical projector. A strip of clean metallic zinc when placed in a lead or in a tin solution brings forth the characteristic growth of these metals. Differential growth may be shown in a solution containing four per cent. potassium ferricyanide and one-half of one per cent. sodium chloride with a little gelatin or albumin added (Figure 4). A piece of iron wire shows rapid growth of crystals on being placed in the solution, while a piece of zinc wire shows little, if any, growth. However, if they are twisted together and placed in the solution, then rapid growth will take place on the

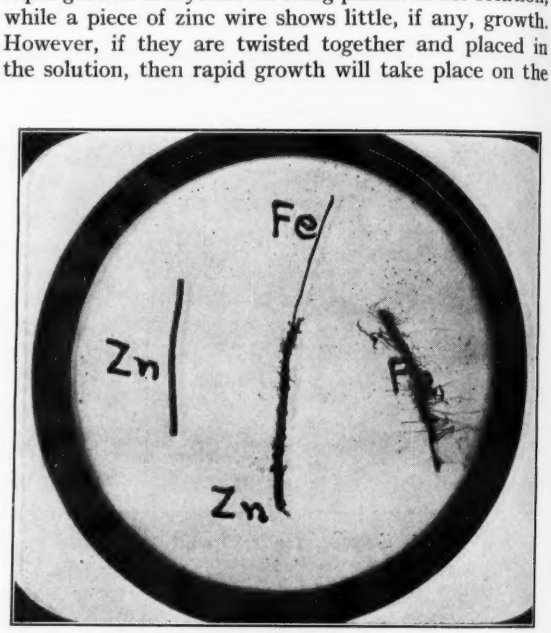

FIGURE 4.—DIFFERENTIAL GROWTH FROM IRON AND ZINC AND AN IRON-ZINC COUPLE IN POTASSIUM FERRICYANIDE

zinc, and the growth on the iron will be inhibited. By cutting them apart, the original conditions are restored. This experiment usually produces considerable student discussion and sets the stage for a detailed consideration of electrochemical phenomena, including the problems of corrosion.

Electrolysis may be demonstrated by placing the electrodes in solution. The demonstration of the breakdown of water is a little more spectacular if a small amount of gelatin or albumin be added to the solution to trap the bubbles as they are formed. Some experiments may be arranged so that the results will appear on the screen before the students. By blowing the breath through a shallow layer of lime water in a small dish on the stage of the projector, the formation of carbonate is readily shown. A simple experiment may be arranged by taking some yeast in a test-tube and bringing a tube from that around so that it dips

[3] RICHARDS, "A rapid method for determining colorimetrically the pH of small amounts of fluids," *Science*, **68**, 185 (1928).

under the layer of lime water. This experiment will proceed on the screen before the students and makes an interesting accompaniment to a lecture on respiration and fermentation.

Polarized light lends itself to many spectacular demonstrations. A piece of Type 2 Polaroid may be placed over the stage opening of the vertical projector and another one on top of the objective. Or, the demonstration kit put out by the Polaroid Corporation may be used held in place with an ordinary laboratory ring stand. The effect of many crystals on polarized light is readily shown on the screen, *e. g.*, medium-sized crystals of benzoic acid, aspirin, hydroquinone, tartaric acid, thymol, potassium nitrate, borax, potassium chlorate, and many others. Recrystallization of spermacetic or palmitic from oil solution and lecithin from absolute alcohol may show liquid crystals in polarized light. The growth of one of these crystals when a seed crystal is placed in a supersaturated solution on the stage is very spectacular when seen on the screen with polarized light. The importance of polarizing light for distinguishing between materials may be demonstrated by showing the effect of Cellophane and Kodapak. These transparent layers have quite different effects on polarized light. A great many experiments may be performed in this manner including all of those included in the Polaroid kit.

The experiments described have been taken from current books and from the experience of the writer and are offered merely to demonstrate the possibilities of this projection lantern. Once one has become accustomed to working on the flat surface it becomes natural to turn to it for many demonstrations where one would like to bring the students up to the lecture desk. A number of experiments may be taken from many of the laboratory books and demonstrated in this manner, restricted only by the limitations of the method. The advantages are that the student's attention is focused on the demonstration and that each student can see equally well and from the best viewpoint. By use of a glass rod or pencil, the instructor may point out regions of special interest in a chemical experiment.

The principles of scientific methods are more readily discussed and demonstrated by means of experiments made on the projector, and many experiments may be made into permanent records by tracing outlines of changing size as mentioned before. Another method which is very effective and interesting is to let the students photograph the results with a medium-fast film and lens. It is usually possible to obtain a picture of the screen with an exposure of about a twenty-fifth of a second. With the exception of a few experiments which require deeper layers or which must be held upright, the lecture-table type of vertical projector is better adapted for most experiments in chemistry and has many real advantages over the more conventional type of lantern-slide projectors.

The UTILIZATION *of a* PROFESSOR EMERITUS, *an* EXPERIMENT

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Baltimore, Maryland

ENFORCED retirement from teaching brings problems. A genuine researcher who has tasted the joys of discovery cannot be happy away from research; a true teacher is desolate without students. How can a professor emeritus keep in touch with research and associate with students? How can he have a royal good time on an emeritus income? An experiment which has largely solved these problems for the writer is here described in the hope that others will make similar experiments and improve upon this one.

It is pleasant to travel, to see new things, to meet worth-while people and converse with them on topics of mutual interest. Where can a chemist find more interesting new things, more worth-while people or more engrossing topics of conversation than in chemical laboratories? It is said that Tommy Tucker sang for his supper. He was fortunate in finding people who appreciated his singing enough to supply the supper. If he did his best at the singing he could eat the supper with a clear conscience. Having an appreciative audience was probably sufficient reward for Tommy, so by getting his supper also he was twice paid. Few chemistry professors can sing well enough to earn a supper, but by the time one reaches retirement age he should have accumulated a lot of experience which may be bartered for entertainment. It seems logical to use the experience, of which he has much, rather than money of which he has little, in paying his way.

The experiment, which has now run two years, is to act as research adviser to a group of institutions. The largest chemical research organizations have consultants who come in from time to time to talk things over with their chemists, so why should the same not be good for universities, even for large ones? Someone coming in from the outside brings a fresh point of view and may dig up from his experience something which may aid in solving the problem in hand. The group of institutions was organized by Professor J. Sam Guy and was naturally in the South on account of the connections this particular adviser had with that section. To save time and expense it is desirable for the places visited to be grouped in one section. In this circuit it is possible to do practically all the traveling on overnight sleepers or in the evenings after working hours.

Experiment has shown that four trips a year are sufficient, one in October to help in the selection and initiation of problems, one in December, and one in February to observe their progress and one in April to assist in the roundup. During the intervals it has been found desirable to have informal biweekly reports. These are written by the student in triplicate, one copy to the professor, one to the adviser, and one retained. These are commented on in a letter to the professor.

Experience shows that the research adviser should be that and only that; he should advise, but not direct. The important thing is to build up research in the institution. The research must be done by professor and students; for them to put their hearts into it, it must be their research. They work day after day throughout the year; they have to take the blame for poor results and must have the credit for good. Naturally, they will want to insert a note of thanks to the adviser for whatever assistance he has given.

It has been found desirable to put emphasis on problems which the particular students can be expected to complete in the time and with the facilities available. The students concerned have been candidates for the master's degree and ambitious B.S. men who had some spare time or who got so interested that they would make it. None of them had time for an elaborate investigation. Besides, they were beginners in research. Not all of the problems undertaken have been finished, but a good proportion of them have been. A number of articles have been published in the *Journal of the American Chemical Society*, and others are in preparation.

From the point of view of the adviser, this two-year experiment has been a decided success. It has provided the opportunity for travel, for contacts with many interesting faculty members and with a large number of ambitious students just starting out to explore the wonders of the unknown. The adviser has been amply repaid for the time spent.

This method of having a good time is recommended to retired professors. The plan here presented has suited a certain group of institutions and one adviser; changes can be made in it to suit others.

STIMULATING CHEMICAL RESEARCH *in the* SOUTH-EASTERN STATES, *an* EXPERIMENT[1]

JOHN R. SAMPEY

Furman University, Greenville, South Carolina

CHEMICAL consultants for industrial concerns are common enough. Indeed, it has been said that there is not an organic chemist of outstanding reputation in the country who does not have one or more such connections. It was not until two years ago, however, that a specialist of wide experience in the academic and industrial fields offered his services to a group of colleges. Dr. E. Emmet Reid, Professor Emeritus of the Johns Hopkins University, recognizing the retarded development of pure research in the Southeastern states, conceived the plan of visiting institutions in this area with the purpose of assisting chemical research among members of the chemistry staff and qualified students. Professor J. Sam Guy of Emory University was interested in the development from the first, and succeeded in organizing a group at the Chapel Hill meeting of the American Chemical Society. The results achieved in this unique experiment in chemical education are of general interest, and while some names

[1] Presented before the Division of Chemical Education at the ninety-seventh meeting of the A. C. S., Baltimore, Md., April 4, 1939.

of individuals and institutions are used in the following report, they are of minor importance in comparison with the general objective of hoping to stimulate further experiments of the sort described.

INSTITUTIONS VISITED

The institutions visited during the first session of 1937–38 were The University of Richmond, Richmond, Virginia; the University of South Carolina, Columbia, South Carolina; Furman University, Greenville, South Carolina; Emory University, Atlanta, Georgia; Birmingham-Southern College and Howard College, both of Birmingham, Alabama. This year Alabama Polytechnic Institute, Auburn, Alabama, and the University of Alabama, Tuscaloosa, Alabama have joined the circuit.

THE PLAN

Dr. Reid has always insisted on the point of view that he is not directing the research of either teachers or students, but that he is seeking to help both by informal advice. All contacts with students are through their professors. At the opening of the session a large number of problems are sent around, each one written up in sufficient detail to show reasons for undertaking it, and the methods, apparatus and chemicals required to attack the solution of the same. These suggested problems are for anyone who wants them. Last year at the University of South Carolina all five students in the project there happened to work on these suggested problems, while at Emory University six out of the eight students were on Dr. Quayle's own problems. Most of these six, however, used compounds which Dr. Reid happened to have in stock from previous investigations of his students. Dr. Quayle was interested in measuring parachors of groups of isomers, and it happened Dr. Reid had just such groups already prepared. The latter's large collection of carefully purified chemicals is drawn upon whenever it can be useful.

By juggling train and bus schedules Dr. Reid manages to spend the working hours of successive days at the various institutions. The consultation periods are spent in informal discussions of problems, considering their difficulties, interpreting results, and planning further experiments. Four trips around the circuit are made; in October, December, February, and April. Between the trips reports of progress are sent to Baltimore. The student writes his results and questions in triplicate; one copy is filed with the professor, one is kept by the student, and one is sent to Dr. Reid. Comments on these are sent to the professor in charge so that he has a complete record, and all concerned are in possession of all the facts.

Emphasis is put on undertaking problems of such a size and nature that there is a reasonable expectation of completing them within the time available. Since the students concerned are beginners in research and have limited time for such work, it means that small problems must be assigned, or small sections of larger ones, but it is demanded that whatever is done be done according to accepted standards of the profession, and suitable for publication in the *Journal of the American Chemical Society*. The contribution may be small, but it must be first class. The problems undertaken are varied in nature according to the interests and experience of those undertaking them.

Last year approximately eight professors and twenty-five students were coöperating; this year (1939) twelve professors and forty students are participating in the plan. In each institution there are more or less transient contacts with other faculty members and students. Dr. Reid's name appears in the faculty lists of some of the institutions as adviser to the chemistry department, but he will not permit his name to appear as a co-author on publications, although naturally notes are inserted thanking him for chemicals or for assistance.

FINANCIAL BASIS

Many who are condemned to live in the frozen North go South to indulge their fondness for fishing, hunting or golf, and pay good money for their fun. It so happens that Dr. Reid does not fish, hunt, or play golf, but he regards chemical research as the greatest sport on earth. He considers himself fortunate to be able to engage in this down South without it costing him anything. The institutions visited put up one hundred dollars a year apiece which pays for traveling expenses, stenographic assistance and other incidentals. At the end of the year what is left over is returned to the subscribing institutions for special chemicals or other departmental purposes.

RESULTS

Two years is too short a period in which to expect many results from the launching of a research program in institutions which have had little time or opportunity for such activity in the past. From the work of last year, however, eleven papers were presented before state and national scientific meetings, and as many more are scheduled for similar meetings this spring (1939). Three articles have appeared in the *Journal of the American Chemical Society* and several others are in preparation on last year's results; there will be a larger number from this year's. Another objective method of evaluating the program is to list some of the contributions made to fundamental research. In addition to the synthesis of more than seventy-five new compounds, the methods of preparation of substances of known structures have been improved; one of the preparations of the latter type has been called for by the editors of "Organic Syntheses." These advances made in purely synthetic work have been matched by studies of the mechanism of organic reactions, rates of reaction, parachor measurements, and so forth.

The mere cataloging of the titles of problems under investigation, the listing of the papers published and read, and the naming of discoveries of scientific significance that have been made, all fail to convey what those closest to this new development of chemical

education feel has been and is the most important contribution made by Dr. Reid in his rounds—I refer to the quickened activity not only of the personnel of the several chemistry departments concerned, but the awakened interest in creative scholarship on the part of other departments of the institutions visited. Dr. Reid is eminently fitted professionally by his years of academic and industrial experience to serve as a consultant in wide fields of organic and physical chemistry. To this breadth and depth of view he adds a freshness of approach to every problem that is contagious to staff members and students alike. It is not surprising to learn that more than half of the students who came under Dr. Reid's influence last year are planning research careers, while this year's group is fired by the same ideals of scientific achievement. But what was not foreseen at the beginning of the experiment is the way this zeal for productive scholarship is working its way into other departments. One such department in a related field of science, which had not produced a publication in the last decade, brought forth a creditable article this spring in the leading research journal in its field. Another good deed was done when an English professor discovered that the same microfilm reader used to bring foreign journal articles of a scientific nature could also give him access to rare manuscripts in his field, and he has become a regular user of this tool of research which should mean much to a section of the country that can boast so few big libraries. In short, it is the studied opinion of more than one observer of this new experiment of chemical education that if the South and Southeast could locate a few more E. Emmet Reids they would pull out faster from their present arrested development in pure science and related fields of creative scholarship than by any other means now at work in these sections.

An IMPROVED DESIGN *for a* LABORATORY TORCH[1]

J. M. KRAPPE

Purdue University, Lafayette, Indiana

OUR efforts to improve the operation of gas torches have all been directed along the lines of making their operation more flexible and convenient for the user. The experimental work was done with various types of torches, some of them especially converted to use natural gas and others of entirely new design. As a result of this work, a new variety of torch having a combination of features not found on any torch available on the market was developed. With regard to types of flame, we desired a torch which would be as flexible as it is possible to make it. It was realized that every type of flame, from a sharp needle-point flame to a large brush flame, was required to handle the work being done in a typical laboratory. Furthermore, the torch had to have flexibility with regard to flame temperature, since all types of glass, from those having a very low softening point to those having the highest softening point, were being used for the purpose of repairing old glass apparatus, or for building new apparatus. The performance of the new design showed that it was possible to obtain good flames with air and gas alone and higher temperature flames with air, gas, and oxygen mixtures.

[1] Torch designed by J. M. Krappe, Associate in Gas Engineering and F. I. Merritt, Department of Chemistry, Purdue University.

FLAMES FOR WORKING GLASS

The principal use found for laboratory torches is in the field of glass working. A wide variation in types of flames is required to perform the various operations. For example, when it is desired to make a glass "*T*," a sharp needle-point flame is essential. This flame heats a portion of the tube about one-fourth of an inch in diameter with the hottest spot at the center. The glass is heated to a higher temperature than that required for ordinary forming, and a hole is blown in the wall of the tubing. The large bushy flames are required for heating large areas and for forming large-size tubing.

The importance of being able to obtain a flame temperature only slightly higher than the working temperature for the particular kind of glass being used can be readily appreciated. If a very hot flame, such as that given by a gas-oxygen torch, is used, the outside surface of the glass melts and runs before the heat has soaked into the interior. This results in the work being spoiled or very poorly shaped. It is essential to have the glass evenly heated before it is formed or worked, and for this purpose a "soaking heat" is preferred.

Table 1 shows the softening temperatures of various types of glasses. For each main class there is a range of softening temperatures shown, since a slight variation in composition results in a slightly different softening

temperature. However, the main classes of glass materials may be seen from the table; and the softening temperature, although lower than the actual working temperature, gives an indication of the relative flame temperatures required.

TABLE 1

SOFTENING TEMPERATURES OF VARIOUS GLASSES

	Degrees C.	*Degrees F.*
Lead glasses	460–640	860–1180
Lime-soda glasses	540–680	1000–1260
Borosilicate glasses	560–700	1040–1290
Barium glasses	640–730	1180–1350
"Nonex" glass*	756	1390
"Pyrex" glass*	820	1510
Fused silica, clear	1430	2600

* Temperatures at which the logarithm of the viscosity is about 4.5.

The flame temperatures obtained on the Purdue torch, starting with a soft air-gas flame, are shown in Table 2. The air-gas-oxygen flame with only a slight amount of oxygen was sufficiently high in temperature to work pyrex glass. In fact, actual experience with the torch showed that the use of excessive amounts of oxygen is undesirable. The last flame described in the table, that is, the one having an air-oxygen ratio of 4 to 1, was too hot for most operations on pyrex glass.

TABLE 2

FLAME TEMPERATURES OBTAINED ON PURDUE TORCH

Type of flame	*Flame temperature* *Degrees C.*	*Degrees F.*
Air-gas flame, soft, no inner cone*	400–840	760–1550
Yellow flame*	920	1680
Air-gas flame, distinct inner cone†	1580–1590	2870–2900
Air-gas-oxygen flame, distinct inner cone; ratio, air to oxygen, 28 to 1	1650–1730	3000–3150
Air-gas-oxygen flame, distinct inner cone; ratio, air to oxygen, 4 to 1	Above 1820	Above 3300

* Measured with a chromel vs. alumel thermocouple.

† Measured with a platinum, platinum-rhodium thermocouple. The thermocouple bead was inserted in the flame just above tip of inner cone for the high temperature flames. The range in flame temperatures given may be attributed in part to variations in placing the thermocouple in the flame and in part to the variation in velocity of the burning air-gas mixture. It was noted that high velocities tended to give higher temperatures due to the higher rate of heat transfer to the thermocouple bead.

FLAMES FOR BRAZING

Brazing alloys having melting points ranging from 1200°F. to 2100°F. are available for the joining of metals. An air-gas flame has sufficiently high temperature to melt the low temperature brazing alloys, but the melting of the alloy is not the principal problem in this operation.

When the alloy is in contact with cold work, higher flame temperatures are required, since heat is conducted away from the flame into the work. Consequently, gas-oxygen and air-gas-oxygen flames are required to heat the object being brazed. In the soldering operation it is necessary to preheat the work thoroughly before applying the solder. For this reason a large brush flame is generally employed. The ratio of air to oxygen required may be adjusted, depending on the size of the work being done. Light weight metal would not require as high a flame temperature as heavy sections.

FEATURES OF THE NEW TORCH

The advantages of the improved construction include flame stability and the ability to obtain either a needle-point flame or a large bushy flame as desired. With the torch developed, small flames were obtained as follows: a one-eighth-inch diameter needle flame with air and gas alone; a one-sixteenth-inch diameter needle flame with air, gas, and oxygen. With gas and oxygen alone, the diameter of the flame is a little over one sixteenth of an inch, but this flame has a very high temperature. Thus, the torch is suitable for doing the finest up to fairly large pieces of glass work. The torch is also very flexible. It may use any one of three mixtures without changing the burner head. It is possible to use air and gas only; air, gas, and oxygen; or gas and oxygen, depending on the type of work being done. In general, higher flame temperatures are obtained by using large proportions of oxygen in the mixture.

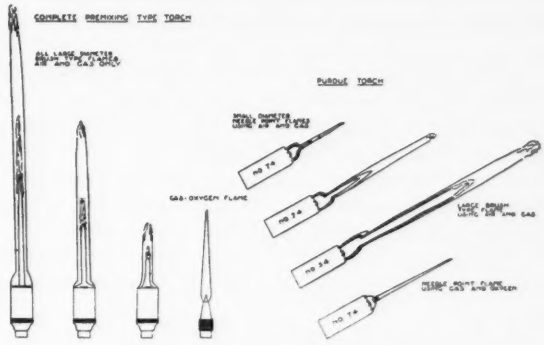

FIGURE 1.—TYPES OF FLAMES OBTAINABLE WITH LABORATORY TORCHES. SHARP NEEDLE POINT FLAMES ARE EASILY OBTAINED WITH THE PURDUE TORCH AND ANY PROPORTIONS OF AIR, GAS, OR OXYGEN MAY BE USED WITHOUT CHANGING THE TORCH HEAD

The sharp needle-point flames are used for spot-heating small areas and have smooth contours showing a clear, distinct inner cone. This contrasts with the soft flame, which is less desirable due to its low flame temperature and large heating area. All of these types of flames may be obtained easily when using the torch on natural gas. As an additional feature, satisfactory flames may be obtained when holding the torch in almost any position.

The flame stability is extremely good. The air valve may be opened suddenly without putting the flame out. In fact, it is possible to turn the air pressure on full (up to fifteen pounds) without extinguishing the retaining flame. The flame is also very stable when the torch is moved around rapidly, as it might be in ordinary handling on the job. The torch can be swung in an arc very rapidly and in a rough manner without blowing the flame out.

The torch is relatively inexpensive, due to its simple construction. It is light in weight for comfortable handling when used as a hand torch. When used as a

bench torch a swivel or ball and socket stand clamps the torch firmly in the desired working position.

The flame-head is designed in such a manner that there is no possibility of back-firing during adjustment. The mixture of gas and oxygen, which often gives difficulty on this score, is made at the tip of the burner, and hence no back-firing can occur.

TORCH CONSTRUCTION

(*1*) *Complete Premixing Torch.*—The best picture of the newly developed torch may be obtained by comparing its construction with that of a complete premixing type of torch. A commonly available design has a chamber just in back of the head in which all the air and gas are mixed. The air and gas pass through a large diameter port around which there are smaller flame retention ports. The mixture comes out of the flame retention ports at low velocity and helps to keep the large flame from blowing away from the port. A

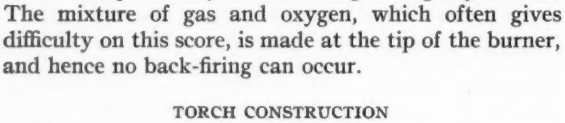

FIGURE 2.—COMPLETE PREMIXING TYPE AIR-GAS TORCH. A SPECIAL HEAD HAVING A SMALL DIAMETER PORT IS REQUIRED FOR USE WITH GAS AND OXYGEN

separate head with a single flame port is furnished for the use of oxygen and gas mixtures. However, neither the oxygen head nor the flame retention head is entirely satisfactory on a mixture of air, gas, and oxygen. When oxygen is used in the mixture, back-firing is very likely to occur during the adjustment. In some cases, this results in the head of the torch blowing off. Furthermore, this type of torch does not give the short, sharp needle-point flame required for heating very small areas.

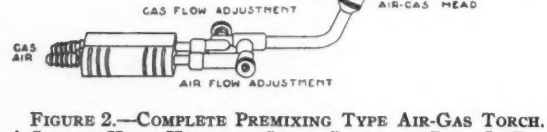

FIGURE 3.—DESIGNER'S MODEL OF PURDUE TORCH. THE FEATURE OF PORTABILITY ALLOWS WORK TO BE DONE ON LARGE ASSEMBLIES OF GLASS APPARATUS WHICH CANNOT BE TAKEN APART. WHEN A STATIONARY TORCH IS REQUIRED, IT IS CLAMPED IN PLACE ON A RING STAND OR IN A BALL AND SOCKET TRIPOD

The flame retention head is a definite aid in maintaining the flame on the burner when a long flame is desired. Both the flame retention device and the flame port are designed for a given maximum rate of air flow, and the flame will go out if higher rates of flow are employed. In principle, the flame retention device is a restricting orifice placed in the air-gas mixture supply to the retention flames. The high pressure of the air-gas mixture is reduced and the mixture at low velocity passes to the retention flame ports.

(*2*) *Purdue Torch.*—The Purdue torch has been designed on an old principle of gas burning. A part of the air required for combustion is inspirated in a manner similar to that in an ordinary atmospheric-type gas burner. Thus, when the gas supply is turned on, a

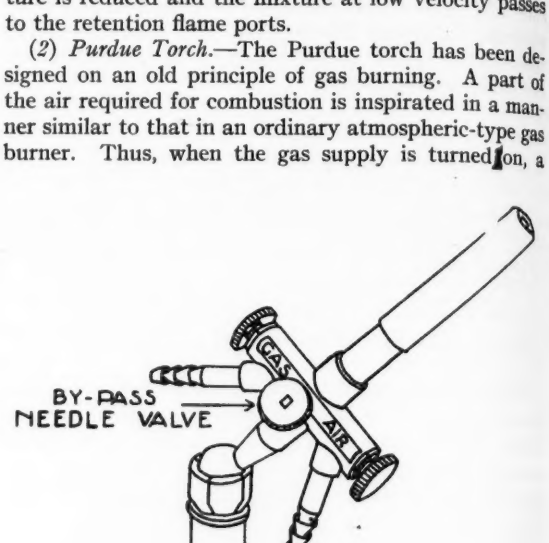

FIGURE 4.—BLAST LAMP CONVERTED TO USE NATURAL GAS BY MEANS OF A BY-PASS NEEDLE VALVE

soft blue flame which may be readily lighted exists at the tip of the torch. The remainder of the air or air-oxygen mixture is injected into this soft flame at high velocity by means of a small air orifice. Figure 3 shows the essential arrangement of such a torch. A needle valve controls the gas supply to the torch, while an air-cock or screw-clamp on rubber tubing is used to control the air supply. An air shutter is supplied to control the amount of primary air to the soft blue flame. The oxygen is mixed in with the air supply by means of a glass tee in the air line, and its flow is regulated by means of pressure reducer supplied with the oxygen tank.

AIR-PRESSURE VARIATIONS

Assuming that the operator has adjusted the torch controls for the type of flame he desires, air-pressure variation seems to be the main source of difficulty thereafter. Sudden variations are more disastrous than a gradual variation, since a sudden change in air pressure may cause the flame to go out. Gradual variations in air pressure also lead to difficulties in delicate glass-blowing work. After the operator has adjusted his flame for certain flame characteristics which he knows

are desirable for the work he is doing, a change in air pressure will cause the flame to change its characteristics so that the operation cannot be finished until a readjustment of the controls is made. As long as the pressure variations are not too frequent and too violent it is possible to maintain the same characteristics of flame by making slight adjustments to the needle valve in the gas supply. Apparently, this is the easiest way to make small changes to compensate for variations in air pressure. Of course, the control on the air supply could also be operated, but the adjustment is not as easy to make, due to the higher air pressures available. In other words, a small movement of the air valve results in a very large change in the rate of air flow.

As an example, experience with a small dental type of torch may be cited. A small air compressor when set for a low outlet pressure gave unsatisfactory operation due to pressure variation. The flame constantly changed its appearance and occasionally went out. However, when the operator adopted a technic of setting the compressor motor for a higher pressure and throttling the air supply down by means of the needle valve on the torch, his flame became much more stable. The operator now leaves the needle valve controlling the air supply in a fixed position and obtains a soft, bushy flame or a sharp, pointed flame by merely adjusting the needle valve controlling the gas supply.

Some experimental work was performed with control valves with the following results. With two control valves in the air line, a pressure variation of six per cent. in the supply was reduced to a variation of only one and one-half per cent. at the torch. In another test with an entirely different setting of the valves, the pressure variation of six per cent. in the supply was reduced to one-tenth of one per cent. at the torch. The results show that valves in the line, if throttled carefully, can reduce the pressure variation to almost nothing. In a third test with an air-pressure regulator, a variation of six per cent. in the supply was reduced to one-tenth of one per cent. at the torch.

Gradual variations in air pressure also lead to difficulties on delicate glass-blowing work. After the operator has adjusted his flame to a fine needle point or for a certain flame appearance which he knows is desirable, a change in air pressure will cause the flame to change its characteristics so that the operation cannot be finished until a readjustment of the torch is made. In general practice, air is delivered from two pounds to ten pounds per square inch in laboratory air lines. Actually, the pressure required at the torch head is exceedingly small. For example, the torch using a premixing of air and gas in back of the head requires a pressure of only fifteen inches water column, or about one-half pound at the torch tip. Ordinarily the high line pressure is reduced successively by a valve in the air line and by the valve on the torch. The high air-line pressure, as cited, cannot be considered disadvantageous. Actually, there is a certain amount of pressure variation in service. For example, if one torch is in use on the line, the turning on of additional torches will interfere with the operation of the first one. These variations in pressure are due principally to the sudden drain on the air line when the additional torches are turned on. However, if the initial high pressure is throttled at the torch, difficulties due to air pressure variation may be reduced.

CONVERTED BLAST BURNERS

These laboratory blast burners originally used the nozzle-mixing principle. They were converted to use natural gas and air by building a by-pass into the barrel of the burner and gave fairly satisfactory results. This by-pass is an adjustable needle valve which is designed to allow a portion of the compressed air to mix with the gas in the barrel. With this device, satisfactory needle-point flames may be obtained on natural gas. In comparison with the Purdue torch, it may be said that the converted blast burners are not as easily adjusted for the various needle-point flames required. The reason for this is apparent when examination of the construction is made. The amount of air flowing through the by-pass depends on the setting of the main air valve, and hence must be reset with every change in flame type. As a result, considerable manipulation of both the main air valve and the by-pass are required before the desired type of flame can be obtained. With the Purdue torch it is easier to adjust for the needle-point flame, since the air-gas mixture going to the burner head is independent of the compressed air supply.

PHILLIPS MEDAL AWARD

It has been announced that the University of Pittsburgh has awarded the Francis Clifford Phillips Medal in Chemistry for 1940 to Fred Thomas Fiedorek. Mr. Fiedorek has the highest academic rating of the science students who are to be granted the Bachelor of Science degree in chemistry. He is a member of Sigma Xi, Phi Lambda Upsilon, and Pi Tau Phi.

AIMS *or* OBJECTIVES *of* QUALITATIVE ANALYSIS[1]

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State Teachers College, Montclair, New Jersey,
W. P. CORTELYOU,
Tubize Chatillion Corporation, Rome, Georgia,
AND
ALEXANDER CALANDRA
Brooklyn College, Brooklyn, New York

A SURVEY has been made of the aims and objectives of qualitative analysis, with the basis of judgment the statements made by the authors of certain standard textbooks and educational journal articles. Questionnaires were carefully prepared. One of these questionnaires was submitted to each of the teachers of qualitative analysis who met at Chapel Hill in April, 1937. Others were mailed to over two hundred additional teachers of the subject in all parts of the country. From their one hundred twenty replies an evaluation of the aims was prepared. A considerable variation of opinion was found, particularly in regard to the comparative weights of various aims listed.

Some teachers of general chemistry have felt a need for a section on Qualitative Analysis in the Coöperative Chemistry Test. Others felt that a separate test on qualitative analysis should be prepared. Such a test might be utilized either to guide students in deciding whether they should continue work in analytical chemistry, or to determine whether a transfer student from one college had mastered a course in his first college equivalent to the one offered in the second college. Still other teachers questioned whether such a test could be prepared, or whether mastery of qualitative analysis could be measured by any pencil and paper tests. These divergent views suggested the following questions which should be answered prior to preparing any examination in the field of elementary qualitative analysis:

(*a*) What are the aims of qualitative analysis?
(*b*) Is qualitative analysis given as a part of general chemistry or as a separate course?
(*c*) What is the length in semesters of such a course?
(*d*) What is the credit in hours allowed for such a course?
(*e*) What are the prerequisites for the course?

This paper reports the results of the investigation of these questions.

[1] Presented before the Division of Chemical Education at the ninety-sixth meeting of the A. C. S., Milwaukee, Wis., September 7, 1938.

OBJECTIVES OF QUALITATIVE ANALYSIS AS STATED IN THE LITERATURE

To ascertain the opinions of authors and writers on the objectives of qualitative analysis an investigation was made of the preface and introductory chapters of their textbooks and of journal articles on the teaching of the subject. This investigation indicated some variation of opinion among authorities, but the prevalent tendency was to consider qualitative analysis a vehicle for teaching the theoretical basis of the subject and an organized presentation of the properties of substances, rather than to regard the course as an attempt to develop analysts.

Cornog (*1*) states, "Training in the skills of qualitative analysis is no longer one of the chief or very important parts of a chemist's training. Yet today the subject is taught because we know no other teaching mechanism that gives students first-hand experiences with a larger number of chemical materials, chemical reactions, and chemical principles, with less expenditure of student time and effort. Of course, familiarity with the manipulative skills of qualitative analysis still facilitate the progress of laboratory work, but the student who thinks that the chief aim is 'getting out' the metallic ions in a series of samples of unknown composition is laboring under a misapprehension of the purpose of taking a 'course in qualitative analysis.'"

It is Curtman's opinion (*2*) that "Modern qualitative analysis not only considers the various laboratory procedures which the chemist employs in identifying substances, but it also concerns itself with the laws and theories which supply the rational interpretation of these methods."

Hogness and Johnson (*3*) state, "The primary aim of a course in qualitative analysis some few years ago was chiefly to give instruction in analytical procedure and technic. More recently, however, there has developed a marked tendency to place more and more emphasis on the application of the fundamental concepts of solution to the laboratory work. Apparently this movement is still growing, and attempts are being made to adjust the subject matter to the course accordingly.

"In the elementary course the student gains some idea of the properties of the ions and some acquaintance with the concept of equilibrium. Yet it has been our experience that the training alone is not sufficient to serve as a basis for later work in chemistry and its related fields. In its newer development qualitative analysis offers an excellent opportunity for the student (1) to get a better knowledge of the properties of ions and their compounds, (2) to acquire a thorough understanding of the principle of chemical equilibrium, and (3) to acquire training in experimental technic, especially that involving the use of small amounts of material."

McAlpine and Soule (*4*) have a similar opinion, "It is intended to acquaint him with the methods, the resources, and the limitations of chemical analysis. The emphasis is shifting increasingly to a consideration of the theoretical basis of the conditions necessary to obtain satisfactory results.

"The present treatment . . . will lead him to a realization that chemistry is still in the process of development and with live problems available everywhere for one who wishes to work in the field."

Noyes (*5*) states in his preface, "This textbook is an attempt to train the student of qualitative analysis in careful manipulation and exact methods of procedure.

"It is an attempt to make clear to the student the reason for each operation and result, and to accustom him to apply to them the laws of chemical equilibrium and especially the principles relating to solubility and to ionization, complex formation, and oxidation and reduction of substances in solution.

"Qualitative analysis affords an effective means of teaching a part of inorganic chemistry chiefly because it unites into a connected whole a great variety of isolated facts and because the student sees a practical use of the information presented to him."

Yoe (*6*) states, "The purpose of an introductory course in qualitative analysis is twofold: to give the student an opportunity (1) to develop his technic in carrying out not-too-complicated chemical operations, and (2) to study at first hand many of the fundamental principles of chemistry."

Reedy (*7*) has a different view. "For the most part, qualitative analysis is regarded as a service course, retained mainly to furnish a requisite amount of analytical training for students who are going to do their research in some other field.

"The safest and, in the long run, the best objective in a college course of qualitative analysis is the training of analysts.

"The most important objective in an elementary course in analytical chemistry is to defend the student from the view that analytical processes are mainly mechanical."

Sears (*8*) believes in the discipline value. "It has been said that qualitative analysis gives a type of mental training and develops a power of reasoning not equaled by any other course in chemistry.

"We are accustomed to look upon it, it is true, as an independent course fitting in between general chemistry and quantitative analysis and used for the purpose of giving the student a better idea of analytial relationships and to fit him for the more difficult quantitative analysis.

"Qualitative analysis presents useful knowledge which bears a direct relation to both quantitative analysis and general chemistry. It is well adapted for the encouragement of logical thinking and reasoning, and it tends to develop a greater interest on the part of the student."

Town (*9*) believes in the cultural value of the subject. "Teaching qualitative chemical analysis merely to develop analytical skill is not justified in courses containing both professional chemistry students and those taking chemistry for its cultural value alone. However, if qualitative chemical analysis has as its objective an organized presentation of the properties of certain compounds it may be made to make a real contribution to a well-rounded education. This change in objective will also enhance the value of the course for the professional chemistry student. If we start out with the objective that qualitative chemical analysis is an organized presentation of some of the properties of some of the compounds of the elements, then we can point out how these properties may be of value in solving many of the problems that will be presented to our students during their future lives. As a natural consequence of studying these properties in an organized manner the chemistry student will learn of the principles of analysis. In presenting our theories as to why we think certain phenomena occur we are providing the cultural student with working tools of real value that will be an essential contribution toward a well-balanced education."

DISCUSSION

This search of textbooks of qualitative analysis and of journal articles indicates that the objectives of a qualitative analysis course are

(1) To give students a knowledge of the laws and theories which explain chemical equilibria as applied to ionization, complex formation, solubility, and oxidation-reduction.
(2) To give students an organized presentation of some of the facts of inorganic chemistry. This would develop an idea of analytical relationships.
(3) To give a training in laboratory procedure and manipulations which would be of value in more advanced work in chemistry or industrial work.
(4) To give an idea of how a chemist reasons.

EVALUATION OF AIMS OR OBJECTIVES OF QUALITATIVE ANALYSIS

The objectives as stated in textbooks and journal articles showed variation of opinion, and there was no attempt to evaluate them. To gain an idea of the value of the objectives of qualitative analysis a question-

naire covering stated objectives was prepared. The questionnaire also contained inquiries regarding when qualitative analysis was given, the length of time devoted to the subject if a separate course, the credits given, and the prerequisites of the course.

OBJECTIVES OF QUALITATIVE ANALYSIS

Directions: If information were available showing how nearly each of your students had reached each of the following objectives in qualitative analysis, how would you weigh this information in calculating his final mark? Express as a percentage for each with a total of 100. The blank spaces are provided for the addition of objectives which you feel have been omitted and should be included.

Skill in laboratory work as indicated by:

( ) 1. Accuracy in the analysis of simple unknown mixtures.
( ) 2. Skill in laboratory manipulation, determined by observation.
( ) 3. Accuracy, completeness, and neatness in recording data.

Knowledge of the chemistry involved as indicated by:

( ) 4. Ability to quote the known facts regarding the properties of the elements, ions, and compounds actually involved in the analysis.
( ) 5. Ability to complete and balance equations representing reactions actually encountered in the analysis. These equations would be divided into three types as follows: Molecular—%, Ionic—%, Electronionic—%; Total 100%.
( ) 6. Ability to specify what laws and theories are involved in any given step in the analysis.

Ability to apply knowledge gained as indicated by:

( ) 7. Ability to translate the description of an unfamiliar analysis into terms of what the analyst must have found to be present or to be absent.
( ) 8. Ability to solve numerical problems involving equilibrium data (equilibrium constants, solubility products, and so forth).
( ) 9. Ability to specify an adequate short-cut method of analysis when given an unknown whose composition is known to be limited to two or three ions.
( ) 10. Ability to itemize the laws and theories that explain an unfamiliar reaction or analytical step.
( ) 11. Apparent ability to think in a logical, scientific manner, no matter whether speaking of analysis or some other subject, determined by observation.

100%

In your college is qualitative analysis taught:

( ) as a part of the general chemistry course?
( ) as a distinct course for one semester? Credit hours? ( )
( ) as a distinct course for one year? Credit hours? ( )

What are the prerequisites for the course?

( ) none.
( ) one year of high-school chemistry.
( ) semester of college chemistry.
( ) year of college chemistry.

Name of School.....Location.....
Name of teacher making the report.....

Copies of this questionnaire were submitted to the teachers present at the Chapel Hill meeting of the Division of Chemical Education. The teachers were requested to evaluate these aims, add ones which they considered omitted and give the questionnaires to Dr. Cortelyou at the end of the symposium on qualitative analysis or to send them to Dr. Reed at Montclair Teachers College. Subsequently letters containing this questionnaire were sent during the latter part of May, 1937, to forty colleges with a request that the one teaching qualitative analysis evaluate the questionnaire and mail it to Dr. Reed. Twenty-three replies were received.

After a study of these replies the questionnaire was revised to eliminate overlapping questions and to clarify ambiguities of wording.

This questionnaire was submitted to two hundred teachers in colleges all over the country. One hundred fifteen usable replies from the two questionnaires were secured. A preliminary tabulation of the replies from the first questionnaire was made and compared to the data obtained from the second questionnaire. There was no significant difference between the two sets of data. Therefore the data from both questionnaires were combined.

TABLE 1

SHOWING SUMMARY OF DISTRIBUTION BY PER CENT. OF WEIGHT AWARDED TO EACH AIM OR OBJECTIVE OF QUALITATIVE ANALYSIS

Aim or objective of qualitative analysis	*Range*	*Average*	*Median*	*Top quartile*	*Low quartile*	*Interquartile range*	*Rank of average*
(1) Accuracy in the analysis of simple unknown mixtures	2–50	19	15	25	10	15	1
(2) Skill in laboratory manipulation (observation)	0–40	9	10	10	5	5	4½
(3) Accuracy, completeness, neatness in recording data	0–20	6	5	10	5	5	10½
Laboratory Summary	12–75	34	33	40	25	15	
(4) Ability to quote known facts regarding properties of elements, ions, compounds involved in the analysis	0–70	10	10	10	5	5	2½
(5) Ability to complete and balance equations representing reactions encountered in the analysis	0–35	10	10	12	5	7	2½
(6) Ability to specify what laws and theories are involved in any given step in the analysis	0–20	8	7	10	5	5	7
Summary of Facts	5–77	25	25	30	21	9	
(7) Ability to translate the description of an unfamiliar analysis into terms of what the analyst must have found to be present or absent	0–33	7	6	10	5	5	9
(8) Ability to solve numerical problems concerning chemical equilibrium data	0–70	9	8	10	5	5	4½
(9) Ability to specify an adequate short-cut method of analysis when given an unknown whose composition is known to be limited to two or three ions	0–23	8	8	10	5	5	
(10) Ability to itemize the laws and theories that explain an unfamiliar reaction or analytical step	0–25	6	5	10	4	6	10½
(11) Apparent ability to think in a logical, scientific manner, no matter whether speaking of analysis or some other subject, determined by observation	0–25	8	8	11	4	7	7
Summary Applications	10–70	39	34	47	30	17	

Aims or Objectives of Qualitative Analysis.—The data on this question are tabulated in Tables 1 through 4. A study of column one of Table 1 indicates that the range of per cent. value assigned to a particular aim varies greatly with teachers. Aim 4, ability to quote facts, and Aim 8, ability to solve equilibria problems both received from zero to seventy per cent. value. The summaries indicate that in some colleges emphasis is primarily upon laboratory work, in others it is on knowledge of facts; while in others ability to apply knowledge is considered most important. Column two indicates that the average value assigned to an aim varies from six per cent. for Aim 3 (completeness and neatness in recording data) and Aim 10 (ability to itemize the laws and theories that explain an unfamiliar reaction or analytical step) to nineteen per cent. for Aim 1. For most aims the average value is about eight per cent. The median values are lower than the average for six aims and higher for one aim. Apparently from a study of summaries, laboratory work and ability to apply facts are considered a little more valuable than knowledge of facts.

TABLE 2

SHOWING IMPORTANCE OF AIMS OR OBJECTIVES OF QUALITATIVE ANALYSIS WHEN RANKED ACCORDING TO RELATIVE PER CENT. GIVEN BY TEACHERS

Aim or objective of qualitative analysis	*Times ranked highest*	*Times ranked as first three*	*Times omitted*	*Sum of points**	*Importance based on sum of points*
(1) Accuracy in the analysis of simple unknown mixtures	51	81	0	1286	1
(2) Skill in laboratory manipulation (observation)	2	16	7	918	4
(3) Accuracy, completeness, neatness in recording data	0	5	18	675	11
(4) Ability to quote known facts regarding properties of elements, ions, compounds involved in the analysis	2	22	6	938	3
(5) Ability to complete and balance equations representing reactions encountered in the analysis	6	30	3	999	2
(6) Ability to specify what laws and theories are involved in any given step in the analysis	1	18	15	783	7
(7) Ability to translate the description of an unfamiliar analysis into terms of what the analyst must have found to be present or absent	2	9	12	719	9
(8) Ability to solve numerical problems concerning chemical, equilibrium data	4	19	7	869½	5
(9) Ability to specify an adequate short-cut method of analysis when given an unknown whose composition is known to be limited to two or three ions	3	14	8	817	6
(10) Ability to itemize the laws and theories that explain an unfamiliar reaction or analytical step	1	15	11	705½	10
(11) Apparent ability to think in a logical, scientific manner, no matter whether speaking of analysis or some other subject, determined by observation	11	29	26	782½	8

* If given greatest percentage value by professor—a weight of thirteen points was awarded; if next highest, twelve points; if not awarded any value, zero points. Some professors indicated one or two additional aims to the eleven listed above. See Table 3.

TABLE 3

MISCELLANEOUS AIMS AND OBJECTIVES OF QUALITATIVE ANALYSIS

Aim or objective of qualitative analysis	*Number offering aim*	*Range of per cents.*	*Average per cent.*	*Median per cent.*	*Sum of points*
(1) Predictions from the periodic table	8	1–10	4	3½	34
(2) Ordinary chemical arithmetic	7	2–5	4	5	32
(3) Growing interest in chemistry	8	2–7	5	5	22
(4) Accuracy in the analysis of complex substances	2	8½–10	9	9	21
(5) Discussion of analytical procedures in terms of equilibria involved	1	12	12	12	10½
(6) Knowledge of prerequisite chemistry	1	9	9	9	10
(7) Ability to take a theoretical unknown and predict the effect of addition of various reagents	1	10	10	10	9½
(8) Ability to specify adequate abbreviated procedures for various known mixtures of several ions	1	7	7	7	8½
(9) Speed in analysis	1	10	10	10	8
(10) Ability to think	1	6	6	6	5
(11) Ability to interpret and follow a new set of directions or a modification of an old set	1	5	5	5	4½
(12) Effort, faithfulness, and determination, even in case of disappointing progress	1	5	5	5	4½
(13) Promptness in turning in reports	1	5	5	5	4
(14) Anticipating needed materials	1	1	1	1	1
(15) Others (details lacking)	1	20	20	20	11½

TABLE 4

DISTRIBUTION OF EMPHASIS ON TYPES OF EQUATIONS

(*Figures indicate per cents.*)

Type of equation	*Range*	*Average*	*Median*	*Top quartile*	*Low quartile*	*Interquartile range*	*Rank of average*
Molecular	0–100	27	25	40	10	30	3
Ionic	0–100	41	40	55	30	35	1
Electron-ionic	0– 75	30	30	40	20	20	2

A study of Columns 3, 4, and 5 indicates that one-fourth of the teachers would give twenty-five or more per cent. to Aim 1 and an equal number would give ten per cent. or less to the aim. For the other aims the top quartile is at about ten per cent. and the bottom quartile is at about five per cent.

TABLE 5

WHEN OR FOR HOW LONG IS QUALITATIVE ANALYSIS OFFERED

	Colleges
As a part of general chemistry	19
As a part of general chemistry and as a separate course	21
One-semester course only	62
One-year course only	10
Offering two courses one semester, and one-year courses	3

TABLE 6

WHAT CREDIT IS GIVEN FOR THE COURSE IF OFFERED SEPARATE FROM GENERAL CHEMISTRY

	One semester	*One year*
2 hours (semester)	3	—
2½ hours	1	—
3 hours	25	—
4 hours	39	—
5 hours	20	1
6 hours	1	8
8 hours	—	4
No answer	3	1

TABLE 7

THE PREREQUISITES FOR QUALITATIVE ANALYSIS

	Colleges
None	13
One year of high-school chemistry	7
One semester of college chemistry	30
One year of high-school chemistry, and one semester of college chemistry	4
One year of college chemistry	74
No answer	11

A study of Table 2 indicates the importance of Aim 1. It received a point value of 1286 out of a possible 1495 points. It received highest value in fifty-one cases and in thirty other cases received rank of two or three. It was omitted by none. Aim 11—Ability to think in a logical, scientific manner—was ranked but seventh on average, yet it was ranked first by eleven and second or third by eighteen others. It was omitted by twenty-six. Some notes of criticism of this question as being too general were written on the questionnaires. Aim 5—Ability to write equations—was ranked among the first three by thirty teachers.

Teachers of qualitative analysis evidently consider ability to analyze simple unknown mixtures to be the most important aim. Ability to write balanced equations, representing reactions encountered in the analysis, ability to quote known facts regarding properties of elements, ions, compounds involved in the analysis, skill in laboratory manipulation, and ability to solve numerical problems involving equilibrium data follow in the order named. The aim, accuracy, completeness, and neatness in recording data, are least important although of great value to the research worker.

Table 3 lists miscellaneous aims or objectives. The first three were included in the first questionnaire, but because of the low rank given them in the replies were omitted from the second questionnaire. The remaining twelve were added by teachers to the list furnished in the questionnaire.

Table 4 contains the data regarding the division of equations of Aim 5 with types. But eighty-four answers were given. There is evidently a considerable difference of opinion as to the type of equation. Ionic equations are the most frequently stressed type of equations. Electron-ionic equations are next in importance with molecular equations third.

When Is Qualitative Analysis Offered?—The data in Table 5 indicates that qualitative analysis is only a part of general chemistry in but nineteen of the colleges investigated. It is a part of general chemistry and is offered as a separate course in twenty-one other colleges. In sixty-two of the one hundred fifteen colleges it was a one-semester course only. In but thirteen colleges was a year course offered.

Credit for Qualitative Analysis When a Separate Course.—Table 6 indicates the amount of credit for the one-semester course to vary from three to five semester hours. Four semester hours was the median credit. When given as a year course, six semester hours was the median credit.

Prerequisites for the Course.—Table 7 indicates that in seventy-four colleges a year of college chemistry was a prerequisite. However, in thirty colleges, but one semester of college chemistry was required. In four others, one semester of college chemistry plus a year of high-school chemistry was required.

CONCLUSIONS

This investigation indicates that

(1) Qualitative analysis is not a section of general chemistry in two-thirds of the colleges investigated, but is offered most generally as a separate one-semester course.

(2) The credit in semester hours varies from three to five semester hours. For a year course, six semester hours is most frequently allowed.

(3) The prerequisite for the course is generally a year of college chemistry.

(4) The emphasis upon various aims of qualitative analysis varies a great deal.

(5) The authors of textbooks on qualitative analysis and writers of journal articles indicate a shifting of emphasis from the solving of unknowns to the understanding of theoretical considerations.

(6) The six most important aims or objectives of qualitative analysis in the decreasing order of their importance are

(*a*) Accuracy in the analysis of simple unknown mixtures.

(*b*) Ability to complete and balance equations representing reactions actually encountered in the analysis. Ionic equations are most important.

(*c*) Ability to quote the known facts regarding the properties of the elements, ions, and compounds actually involved in the analysis.

(*d*) Skill in laboratory manipulation, determined by observation.

(*e*) Ability to solve numerical problems concerning chemical equilibria data.

(*f*) Ability to specify an adequate short-cut method of analysis when given an unknown whose composition is known to be limited to two or three ions.

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SOME EXPERIMENTS *in* COLLOID CHEMISTRY

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THE increasing application of the colloid point of view to numerous materials, processes, and phenomena brings as a by-product suggestions of experiments which have proved of interest and value. Certain of these experiments have produced methods, modifications of apparatus, or results which may be of general interest. In most cases they were designed to emphasize colloidal aspects of materials and processes of especial interest in the pulp and paper industry, but the principles applied are universal.

FLOCCULATION PHENOMENA

Along with several experiments taken directly from the popular laboratory manuals giving general introductions to colloidal systems and phenomena, is one which demonstrates clearly that colloidal chemistry is really different. The usual ferric oxide sol is prepared by adding ferric chloride to boiling water, and portions of this sol are treated with a few drops of dilute (possibly 0.01 *N*) solutions of sodium hydroxide, sulfuric acid, and sodium sulfate. It is no surprise to see the iron precipitated by the base, but complete and rapid precipitation by the acid and by the salt provides an excellent opportunity to begin the study of colloidal flocculation and to minimize the significance of stoichiometry in such reactions. The importance of particle size and of zeta or electrokinetic potential becomes obvious.

Various other experiments may involve the flocculation of rosin sizes, of alkaline protein dispersions such as that of milk casein or soy-bean protein (determination of the pH of the isoelectric point), and of clay and other dispersions. Of considerable interest is the flocculation of a special wax emulsion (*4*). This consists of paraffin extremely finely divided and highly stabilized by alkaline soy-bean protein and soap. Small amounts of aluminum sulfate or aluminum chloride precipitate the emulsion completely, while larger amounts, added quickly, leave it apparently unchanged. Indeed, these acid systems contain positively charged emulsion particles which are about as stably dispersed as they were in the original alkaline systems. This is a good example of the irregular series (*5*) so often met, and is used to emphasize the danger of excessive amounts of such precipitants and of pH values which go too low.

For many industries, studies of the mutual effect of colloids on each other are instructive. The usual positively charged ferric oxide hydrosol and the negatively charged arsenic trisulfide hydrosol may be prepared, suitably diluted, and then mixed in possibly eight proportions, with the sols themselves at each end of the series. The ferric oxide sols and those containing increasing amounts of arsenic sulfide will require decreasing volumes of dilute sodium sulfate solution for their flocculation, while the stability of the arsenic trisulfide side of the series may be indicated by dilute barium chloride solution. In the series will be one or more systems requiring no salt for precipitation (*11*). The sensitization of ferric oxide by small amounts, and the protective action of larger amounts of gelatin may be similarly shown.

PARTICLE-SIZE DISTRIBUTION

The pedagogical usefulness of the sedimentation balance for the determination of particle-size distribution justifies some efforts to improve it. The excellent outline of Holmes (*3*) serves as a basis. A chainomatic balance serves effectively if the left-hand pan be replaced by a pan designed to catch the sedimenting solid which has been suspended in a high form beaker. With a flat pan, such as is often used, the recovery of

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typical fillers usually runs from twenty-five to sixty per cent. of the amount of solid calculated to be in a cylinder of suspension over the pan. In such cases, the drawing of conclusions from the data on that portion of the solid which happened to stick to the pan seems hardly justifiable. It appeared that the loss was due to solid being carried over the edge of the flat pan by the descending liquid currents, and this is supported by the observation that often the edge of the pan would be bare after a run. A pan with sides (a cup suspended in its center) was prepared, and in several cases over ninety-eight per cent. of the theoretical weight of clay was caught. It must be remembered that a gram of solid in the cylinder of suspension above the pan will not cause an increased weight of one gram even if it is all caught; correction must be made for the buoyant effect of the liquid on each of the weights obtained during the run. On commercial clays the addition of sodium silicate produces an increasing dispersion of the clays and consequent depression of the curves. Size values so obtained are fictitious unless similar dispersive effects are obtained in the actual use of the clays. The swinging of a sensitive balance is effectually damped by surface tension of the liquid acting on the rod supporting the pan. This may be minimized by small amounts of wetting agents on the surface (*9*), although excessive amounts are to be avoided—apparently a low surface tension or a contact angle of 90° would be ideal. Very satisfactory also is the practice of a thin film of kerosene on the rod or over the suspension, where it can also reduce the evaporation rate for long runs.

SURFACE TENSIONS

The du Nouy types of ring method tensiometers permit rapid operation to obtain significant results. Dilution-surface tension runs using various soaps and commercial wetting agents are instructive. The beginning of salting-out action can be detected if one compares the surface tensions of two solutions containing the same concentration of soap, one in water and one in a sodium chloride solution. The salt forces the soap to the surface and thus produces a lower surface tension than is shown without the salt (which by itself raises surface tension slightly). Such concentration-surface tension curves are true adsorption isotherms (*2*, *10*) in which adsorption at the air-solution interface may be studied. In some cases the plot of the logarithm of concentration against the logarithm of the depression of the surface tension seems to consist of two straight lines, as though there were a true solution of soap (or an acid soap) at low concentrations and a colloidal surface active form at higher concentrations.

Adsorption isotherms of surface-active materials on solid surfaces may also be studied by surface tension measurements. The addition of uncooked starch granules to a soap solution causes the surface tension to rise as soap is withdrawn from the air interface to go to the solid. The relative positions of concentration-surface tension curves without and in the presence of starch permits the calculation of the soap adsorbed at each concentration. This method fails utterly for cellulose since many forms of pulp, cotton, alpha cellulose, and so forth, suspended in distilled water lower the surface tension by as much as twenty dynes. The materials responsible have not yet been identified, but it seems possible that such a surface tension lowering may come to be a significant property of pulp or other cellulose forms. In the measurement of interfacial tensions between two liquids, the need for mutual saturation should be emphasized.

VISCOSITY EXPERIMENTS

In the use of the capillary viscosimeters the work may be directed to the demonstration of the isoelectric point as the pH of minimum viscosity for gelatin sols. An additional experiment will emphasize the often-neglected fact (*6*) that the presence of strongly adsorbed ions may have considerable effect on the pH of minimum viscosity. While this is usually found at pH 4.7–4.8, for a high-grade gelatin, the minimum point is shifted to lower pH values by strongly adsorbed negative ions, and to higher pH by similar positive ions. In a series of one per cent. gelatin sols, containing added materials and adjusted by HCl or NaOH to various pH values, the pH of minimum viscosity was found to be as follows.

TABLE 1

Positive ions		*Negative ions*	
2 per cent. Aniline	pH 5.0	0.1 per cent. Duponol (wetting agent)	pH 4.4
0.01 per cent. Night Blue (basic dye)	pH 5.4	0.1 per cent. du Pont Scarlet (acid dye)	pH 4.2

In the study of the starches and their modifications, the MacMichael viscosimeter may be used to show such effects as those of temperature and duration of cook, the action of acids, bases, salts, or enzymes. This apparatus will also throw some light on the mechanism of the flocculation and deflocculation of clays. Clay slips treated with small amounts of sodium silicate promptly drop their readings from about 120° M. to practically zero, then a small addition of alum will restore the original viscosity. In deflocculation, the materials used ranked: sodium silicate, pyrophosphate, hydroxide, tetraborate, (tri)phosphate, with triethanolamine the least effective. In all cases alum additions were able to restore the original high viscosity or even to exceed that of the original clay-water systems. By means of silicate-alum additions the viscosity of a clay slip passed through two complete cycles, thus suggesting a method of commercial control.

ELECTRICAL EFFECTS

Titration in the presence of a glass electrode suggests itself as an indication of adsorption and of the isoelectric point (*7*, *8*). A curve obtained by titrating hydrochloric acid with sodium hydroxide serves as a blank. In the presence of some clay the observed pH values in titration are higher than the blank (sorption of

hydrogen ion) until at pH 3.3 the curves crossed, and above that hydroxyl ions are sorbed selectively. If alum be used instead of HCl, two similar curves are obtained crossing at pH 5.4, again emphasizing the need of stating all the circumstances in giving an isoelectric point. With milk casein in the acid-base titration, there is an excellent separation of curves (strong adsorption) which crossed at pH 4.8, again agreeing with the usual values.

The MacMichael viscosimeter furnishes an unusual method to demonstrate electroendosmose. The rotating cup and the cylinder suspended on the torsion wire serve as one electrode, while a copper ring suspended in the clay slip midway between the cup and cylinder serves as the other. In the usual clay slip the clay particles are negatively charged and the water positive. Closing a direct current circuit makes the reading drop nearly to zero as the water is attracted toward the negatively charged cup and cylinder which become covered with a film of water (*1*). If the opposite electrical connection is made, dehydrated clay builds up on the positively charged cup and cylinder, and the viscosimeter reading rises far above the original value. If the current is left on very long in this direction, the slip around the copper ring becomes quite dilute, and the reading drops, because the clay deposit on the rotating cup is unable to twist the similar deposit on the cylinder through the low-viscosity intervening layer.

Since these experiments have been largely exploratory runs on commercial materials, few results have been included except to indicate the magnitude of effects to be expected. The sole purpose has been to outline a few methods of investigation that may prove of interest and value to others. The coöperation of a number of students is gratefully acknowledged.

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A SENSITIVE STUDENT BALANCE

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IN RECENT years the balance has become an important tool in the laboratory phase of first-year chemistry. The newer manuals emphasize the quantitative experimental evidence underlying the fundamental concepts of the subject, thus following the historical method in the laboratory development of the course. The problem of providing adequate facilities for this type of work is no easy one when viewed in the light of small budgets and the high cost of satisfactory balances. This problem in our institution forced me to resort to the "law of necessity" and invent a style of instrument which has demonstrated its merits during the past semester. I constructed five of these "junk balances," all of equal sensitivity, although no two are exactly alike in minor details, this indicating that a satisfactory balance of this type is not an accidental creation, but can be readily duplicated.

The cost of material is negligible, the construction simple, and a minimum amount of time is required for its completion. Next year we plan to have each student build one for his individual use and bring him in first-hand contact with the fundamentals of balance construction and maintenance.

An approximate list of materials includes a wide-mouth salt bottle of about five hundred grams capacity with a cork to fit; two short lengths of 6-mm. glass rod; two wire paper clips; four one and one-quarter inch slender shank screws; a stove bolt one and three-sixteenths of an inch by two inches; two two-inch iron or brass strips; some sheet tin (from a coffee can); some linen thread or fishline; one one-fourth of an inch triangular file; one wire clothes hanger and a rectangular parallelepiped of light wood, 20 cm. × 4 cm. × 2 cm. for the beam. If carefully cut, the symmetry of the latter permits an easy determination of its geometric center. A bit of adhesive tape and a fine needle complete the requirements.

The center of a side face of the wood bar is located,

and a hole drilled just large enough to allow the file knife-edge to pass through. A three and one-half cm. length of the latter is broken off, and two faces ground smooth on carborundum until a sharp edge is formed at the junction of these faces. The hole in the bar is

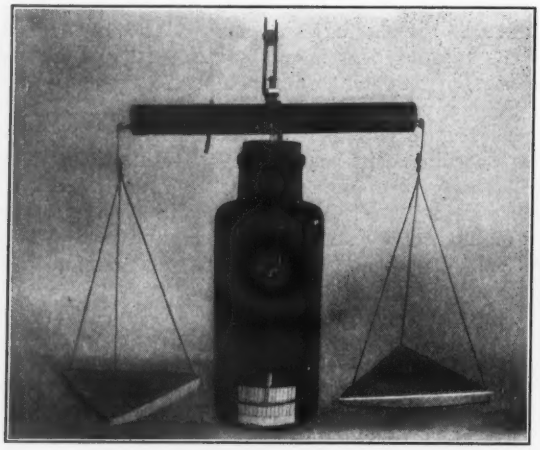

FIGURE 1

bushed with a piece of tin, the knife-edge inserted in position at a right angle to the bar and one or two long wood screws screwed down from the top of the beam directly above the knife-edge so as to hold it firmly in position. By the use of a straight edge a line is drawn lengthwise of the beam tangent to the knife-edge and parallel to the sides. This is done on each face, and the lines are joined across the ends. Two slender wood screws are screwed into the ends so that the rims of the heads extend about 0.5 mm. above the plane of the lines. A sharp notch is cut on the top of the screw head to a depth of 0.5 mm. while holding the file at a seventy-degree angle to the above plane.

A 20-cm. length of heavy wire cut from the coat hanger is inserted in one end of the beam above the notched screw and a long, heavy, screw in the other end for a counterbalance.

Pan stirrups are made of elongated C-shaped pieces of wire cut from wire paper clips. The pans are triangular pieces of tin with turned-down edges and spun concavities in their centers, suspended by short lengths of linen thread or fishline.

Two short lengths of glass rod inserted vertically through the cork of the salt-bottle support comprise the knife-edge supports of the balance. Their upper ends have been notched by softening in a hot flame and immediately forcing the plastic terminals against a ninety-degree metallic edge, holding the rod at a slight angle to the edge so as to give a sloping edge. It is well to make several of these at one time, as not all will be equally good, and some can be held in reserve for replacements. In fact, the ease of replacement of wearing parts is one of the best features of this design. Our soft glass rods have been replaced but once during the past semester. Pyrex rods would be more durable.

The pointer scale in the type favored by my students is a graduated card attached by paper clips to an inverted J-shaped piece of heavy wire with a closed loop on the shorter limb to limit the motion of the pointer. The longer limb of the J is forced through a cork in a bottle of suitable height. When arranged as shown in the photograph the loop-stop permits the removal or addition of objects with a minimum disturbance of the system. Pieces of wire or wire solder wrapped about

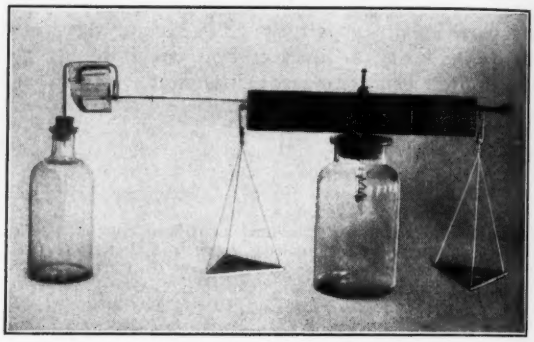

FIGURE 2

the screw above the knife-edge serve to raise the center of gravity. In lieu of these, two rectangular strips of metal are screwed by one end to the back face of the beam at equal distances from the knife-edge. The latter arrangement is preferred as they both serve to counterbalance as well as raise the center of gravity.

The equality of beam-arm length is established by screwing one pan support screw in or out and filing new notches until a satisfactory adjustment is obtained. A pin or needle is attached to the pointer end to permit finer readings.

In the second type shown, the constructional difference lies chiefly in the use of a small bolt to hold the knife-edge in position, as well as support the pointer and the wire-and-small-bolt device for altering the center of gravity. The beam is a short section of broom handle. Wire riders of suitable weight are used for the final adjustment.

If care be taken to insure sharp knife-edges, glass notches that do not bind the knives, knife-edge and pan support notches in one plane and the center of gravity of the system only slightly below this plane, the average balance will show a sensitivity of from 1 mg. to 5 mg. for a load of one to fifty grams. With extra care in construction and adjustment and protection from air currents they approach an analytical balance in sensitivity.

A FLEXIBLE STUDENT CONDUCTIVITY BRIDGE ASSEMBLY

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I. INTRODUCTION

SEVERAL conductivity bridges have been described recently,[1] which offer considerable improvement over the performance of the slidewire-hummer bridge for student use. However, these setups have two disadvantages in such use. First, the appearance of the apparatus is such that it is not obvious to the student that he is working with a Wheatstone bridge. Second, each set is designed as a separate unit which makes it difficult to use a number of them efficiently in any but the smallest classes.

The bridge here described has been designed (1) to look like a Wheatstone bridge and (2) to operate from a power supply common to it and several other similar bridges. Each student (or group of students) performing an experiment has his own set of measuring apparatus, but each set is connected by a plug to the same power supply. The power supply may be used with as many as ten or twelve sets. Each individual set consists of an oscillator, a resistance box, headphones, two variable condensers, and a control panel. Upon this control panel the four arms of the Wheatstone bridge are laid out in such a manner that the bridge itself serves as the only wiring diagram the student need consult.

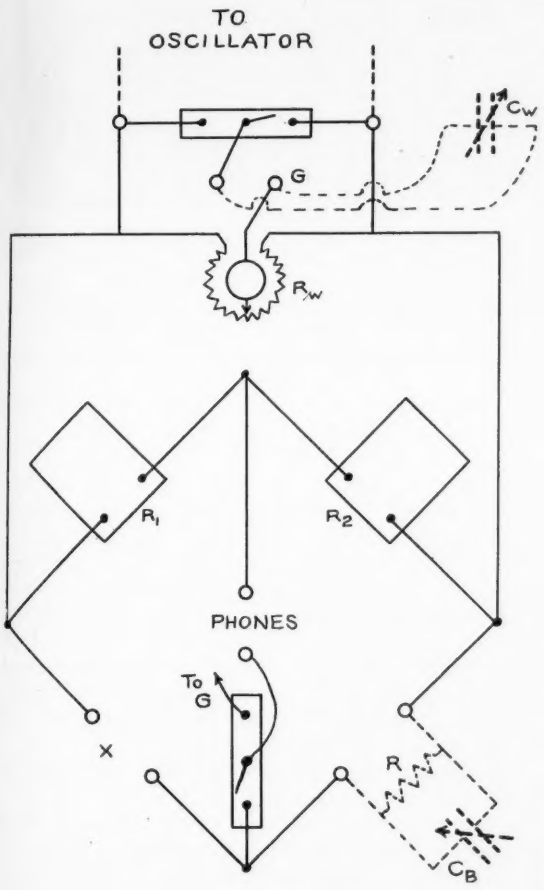

FIGURE 1

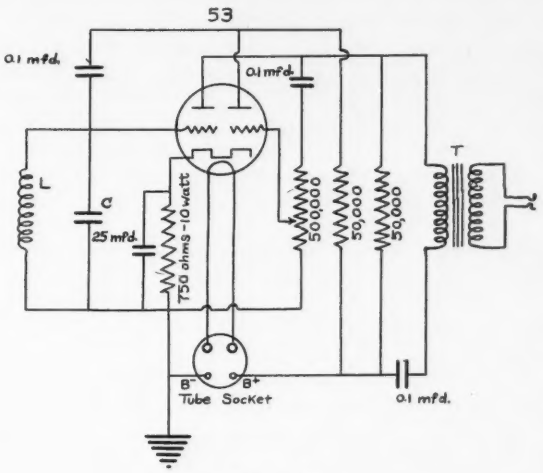

FIGURE 2

The sensitivity of the bridge is considerably better than 0.1 per cent. (When measuring resistances above 1000 ohms, it is better than 0.01 per cent.) The accuracy is also better than 0.1 per cent., provided a good resistance box is used. Such accuracy is greater than that usually needed for student use. No sound whatever can be heard in the phones when the bridge is balanced.

The cost of a number of outfits is less than the cost of the same number of any other type of which we know. This is true even if the cost of having them assembled by a radio repair man must be included.

[1] For example, *Cf.*, EVANS, THIS JOURNAL, **15**, 389 (1938); HATFIELD AND STRICKLER, *ibid.*, **15**, 381 (1938).

II. THE BRIDGE NETWORK

The diagram of the bridge is given in Figure 1 and its photograph is given in Figure 4. The plywood board has dimensions of twelve by fifteen inches and is varnished with two coats of bakelite spar varnish. The ratio-arms are General Radio type 500 plug-in resistors. One of 100 ohms, one of 1000 ohms, and two of 10,000 ohms resistance will give sufficient variation in the ratio of the arms for most purposes. For many measurements the bridge can be used as an equal ratio-arm bridge and the resistance of the cell will be given directly by the reading of the resistance box (R in Figure 1). The two 10,000-ohm resistors should then be used as ratio-arms. If one of the 10,000-ohm resistors is replaced by the 100- or 1000-ohm resistor, then the reading on R must be multiplied or divided by one hundred or ten as the case may be. If an 11,110-ohm three-dial box is used for R, the range of the bridge is 1,111,000 ohms. A four-dial 11,111-ohm box will, of course, make for greater convenience in reading with less changing of the ratio arms.

In tests, the same resistance measured with different ratios of the plug-in resistors gave the same resistance reading within less than 0.1 per cent. With the oscillator output transformer used, the sensitivity of the bridge falls off rapidly if the impedance between the oscillator terminals becomes less than about 500 ohms. The cell constant of the measuring cell should be so chosen as to make the resistances of the solutions come in the range of 200–100,000 ohms. In measuring resistances approaching the lower limit it is advisable to use a ratio of plug-in resistors such that R has as high a value as possible. In any case either one or the other of the 10,000 ohm resistors should always be plugged in.

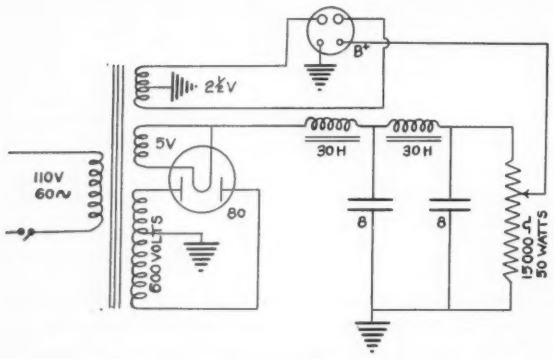

FIGURE 3

To secure a silent balance requires a capacity balance and a proper grounding system. The Wagner ground has been described several times.[2] R_W (Figure 1) may have a value of 50,000 ohms. C_W and C_B may be three-gang radio tuning condensers. Two or three sections may be connected together in parallel as demanded by the characteristics of the output transformer in the case of C_W, or by the capacity of the cell in the case of C_B. The Wagner ground must be rebalanced for every resistance reading. To balance the bridge proper, C_B and R are adjusted together until no sound is heard in the phones. Binding post G is connected to ground through a near-by water pipe. The oscillator ground lead may be brought to G or directly to a water pipe.

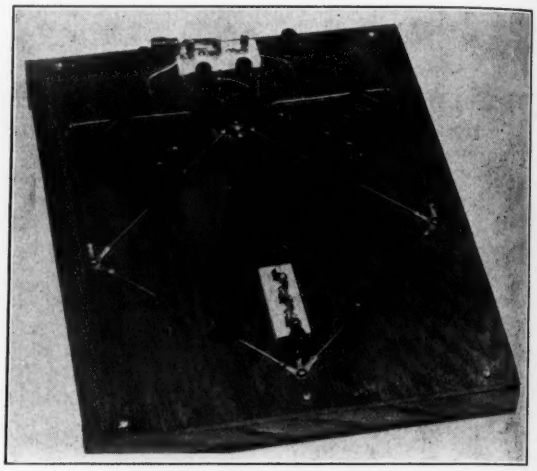

FIGURE 4.—THE BRIDGE

III. THE OSCILLATOR

The oscillator is shown in Figure 2. The circuit was taken from an R.C.A. bulletin[3] and modified to secure a higher output voltage. The original form of the oscillator is in use in this laboratory with a precision bridge and is, everything considered, probably the best available for the purpose. Its distortion-free output of 0.5 volt is, however, too low for use with a student-type bridge when no amplifier is used between bridge and phones. By changing the output leads from the grid coil to the proper plate resistor the distortion-free output voltage becomes about 10 volts.

The oscillator is inexpensive and easy to construct. L is a 1500-turn honeycomb coil. C is a 0.1 MFD. and two 0.01 MFD. paper condensers in parallel. T is an inexpensive 2:1 or 3:1 audio transformer. The parts are mounted in an eight-inch cubical shield with hinged top.[4] The 500,000 ohm regeneration control is mounted on the front panel. The four-prong socket for the

[2] EVANS, THIS JOURNAL, **15**, 389 (1938).

[3] "Technical Service Bulletin TS-2," R.C.A. Manufacturing Company, Inc., Harrison, New Jersey, p. 97.

[4] All the parts are easily obtained from amateur radio shops or catalogs except the 1500-turn honeycomb coil. It may be obtained from the Radio Shack, 167 Washington Street, Boston, Massachusetts.

power supply plug is placed on the rear panel. The output jack, which must be insulated from the case, is placed on one side.

When L and C have the values given, the frequency of the oscillator output is approximately 1100 cycles. When the regeneration control is properly adjusted the voltage will be about 10 volts practically distortion-free as shown by a cathode-ray oscilloscope. The control is adjusted by turning the knob until the 1100-cycle note is heard, then retarding it until oscillation stops, then advancing it slowly until oscillation just begins again.

IV. THE COMMON POWER SUPPLY

The power unit which supplies filament and plate voltages to all the oscillators is conventional in design. Each oscillator requires 2.0 amperes at 2.5 volts for the filament and 3.5 milliamperes at 250 volts for the plate of the 53. The transformer in the power supply must be chosen according to the maximum number of oscillators to be used. In case as many as eight or ten are needed it is probably best to use an extra 2.5-volt filament transformer for the filaments of half of them. Since the filament current is so high, each pair of filament leads to the oscillators should be taken off as close to the power supply plug as possible. Heavy lamp cord should be used. The whole assembly should be grouped about the thermostat in which the conductance cells are placed in such a manner as to make the power leads to the oscillators as short as possible. Each oscillator should be four or five feet away from the other parts of each set.

V. SUMMARY

(1) The bridge assembly described is flexible. Several measuring sets may be used with the same power supply. The bridge networks are fitted with plug in resistors for the ratio arms. Thus the measured resistance can be read directly or in multiples of ten.

(2) The bridge network is designed to look like a Wheatstone bridge.

(3) The bridge balance is sharp to better than 0.1 per cent. No sound can be heard when the bridge is balanced. Depending on the resistance box used, the accuracy of measurement may be better than 0.1 per cent.

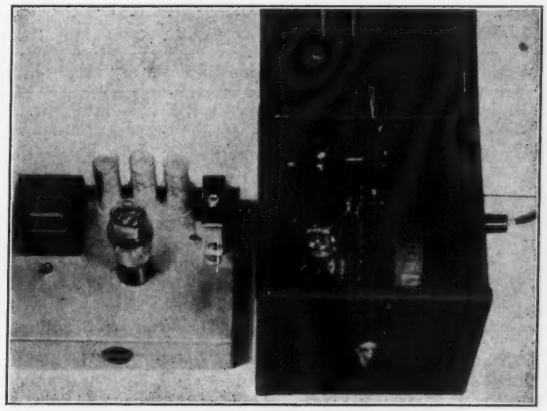

FIGURE 5.—THE POWER SUPPLY AND OSCILLATOR

(4) An adaptation of a new low-distortion oscillator provides a simple and inexpensive oscillator for each measuring set.

(5) The assembly is inexpensive and easy to construct. The cost of each set exclusive of the resistance box is approximately twenty-five dollars. The cost of the power supply to all the sets is about nine dollars.

A SCHEME *for* QUALITATIVE CHEMICAL ANALYSIS EMPLOYING SPOT TESTS

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THE present scheme of analysis for basic radicals is a complete one It adopts as a basis the hydrogen sulfide method of separation into groups, but then uses "special" reagents for the identification of the members of each group, instead of the often very complicated chemical separations of the older methods. This scheme is an adaptation of the very comprehensive system of chemical analysis in use at the Technical University of Delft.[1] In its present form the scheme only deals with the identification of the more commonly occurring basic radicals, and in many cases the special

[1] NIEUWENBURG AND DULFER, "A short manual of systematic qualitative analysis by means of modern drop reactions," Amsterdam, 1935.

TABLE 1

GROUP 1. Add hydrochloric acid to the hot solution of the substance. Filter.

Residue (Group 1*A*). AgCl, Hg_2Cl_2: Wash with hot water, rejecting the washings. Wash with ammonia.

Residue, Black—Hg_2^{++}.

Washings: Make slightly acid with hydrochloric acid. Precipitate: AgCl. (Confirm by Test 1.)

Filtrate: Allow to cool. Filter.
White, crystalline residue (Group 1*B*). $PbCl_2$. (Confirm by Test 2.)

GROUP 2. Filtrate Groups 2, 3, 4, 5 and 6. Oxidize with bromine water, boil, bring acidity to about 2 *N* hydrochloric acid. Pass in hydrogen sulfide for five minutes, then dilute with water until acidity is about 0.2 *N* hydrochloric acid (test with methyl violet paper), and pass in hydrogen sulfide for fifteen minutes. Filter.

Residue (Group 2). Wash with very dilute ammonium nitrate solution, rejecting the washings, then with hot 2 *N* sodium hydroxide.

Residue, HgS, PbS, CuS, CdS, and Bi_2S_3: Treat with hot nitric acid (1:1).

Residue, HgS: Dissolve a small portion in bromine water, and apply Test 3.

Washings: Divide into 2 parts.
(1) Add an excess of ammonia: blue coloration indicates *copper*. (Confirm by acidifying a drop with sulfuric acid, and continuing with Test 4.) Filter. Test a portion of the residue for *bismuth* by Test 5, and wash the remainder with very dilute sulfuric acid, followed by water. A residue indicates *lead*. (Confirm by Test 2.)
(2) Add excess sodium hydroxide. Filter. Wash residue with water and test it for *cadmium* by Test 6.

Alkaline washings: Add an equal volume of concentrated hydrochloric acid, gently warm for some time. Filter.

Residue, As_2S_3. (Confirm by Test 7.)

Filtrate: Boil to remove all hydrogen sulfide.
(1) Test 2 or 3 drops for antimony by Test 8.
(2) Reduce 1 cc. with aluminium. Filter. Test a drop of the filtrate for tin by Test 9.

GROUP 3. Filtrate Groups 3, 4, 5 and 6. Boil in order to remove hydrogen sulfide and to reduce the bulk. Add bromine water and remove the excess by boiling. Add 1 g. of solid ammonium chloride and excess of ammonia (sp. gr. 0.880). Warm until the mixture just commences to boil. Filter.

Residue (Group 3). $Fe(OH)_3$, $Al(OH)_3$, $Cr(OH)_3$ (possibly some $Mn(OH)_2$). Treat with excess hot 2 *N* sodium hydroxide.

Residue, $Fe(OH)_3$, $Cr(OH)_3$, (and $Mn(OH)_2$). Test small portions for *iron* by Test 10, for *chromium* by Test 11, and for *manganese* by Test 12.

Alkaline washings: Apply Test 13 for *aluminium*.
Note: Some of the chromium may dissolve here; it does not, however, interfere with the aluminum test, but can be reprecipitated by further boiling of the alkaline washings.

GROUP 4. Filtrate Groups 4, 5 and 6. Pass hydrogen sulfide for several minutes into the hot filtrate. Filter.

Residue (Group 4). NiS, CoS, MnS, and ZnS (possibly some Cr_2S_3): Dissolve in a little concentrated hydrochloric acid (it may be necessary to add some hydrogen peroxide to complete solution). Boil off most of the acid and then add a little water. Test portions of the resulting solution for *nickel* by Test 14, for *cobalt* by Test 15, for *manganese* by Test 12, for *zinc* by Test 16, and for *chromium* by Test 11.

GROUP 5. Acidify Groups 5 and 6 with glacial acetic acid and boil to remove hydrogen sulfide. If necessary filter—rejecting any residue.* Then make slightly alkaline with ammonia and add ammonium carbonate. Warm for a few minutes. Filter.

Residue (Group 5). $BaCO_3$, $CaCO_3$, $SrCO_3$: Pour a small amount of dilute acetic acid over the residue. Warm the washings to drive off carbon dioxide. Add† potassium dichromate solution and some sodium acetate. Filter.

Residue, $BaCrO_4$—yellow.

Filtrate: Warm, add solid sodium carbonate. Filter, and wash the residue with water—reject the filtrate and washings. Residue: Pour over the filter paper a *small amount* of dilute acetic acid. Test washings (*a*) for *calcium* by Test 17, and for *strontium* by Test 18.

* If manganese has already been found, it is as well to remove remaining traces by adding at this stage ammonia and hydrogen peroxide.
† Test a portion for barium, if there is none present, proceed to the separate tests for calcium and strontium at (*a*).

Filtrate GROUP 6. Divide into two parts.
(1) Smaller part: Add ammonium phosphate and allow to stand. The precipitate of ammonium magnesium phosphate is collected and mixed with sodium hydroxide. Then apply confirmatory Test 19 for *magnesium*.
(2) Larger part: Evaporate to dryness to remove ammonium salts. Add water. Divide the aqueous extract into two parts, and test one part for *potassium* by Test 20, and the other for *sodium* by Test 21.
Boil a portion of the original substance with sodium hydroxide solution. An *ammonium salt* is indicated by evolution of ammonia (odor and action on moist litmus paper).

tests are adapted from those described in the publication, "The B. D. H. Book of Organic Reagents."[2]

The method has several commendable features. It uses smaller quantities of original substance and is therefore especially economical in all the reagents used. It might be argued that explanations of some of the tests are obscure, but, on the other hand, others are very instructive (complex formation, adsorption, and so forth). The analyst's main task, however, is identification, and the present scheme offers considerable advantages in rapidity and certainty. Some radicals, for example tin and antimony, which create much difficulty in the ordinary way, are now identified with the greatest of ease and with absolute certainty.

Before commencing the systematic analysis, a preliminary examination should be made in the ordinary

[2] "The B. D. H. book of organic reagents," 6th ed., The British Drug Houses, London, England, **1937.**

way. The sample is prepared and a solution made for the systematic separations as usually recommended, but using not more than 0.3 gram of the material. Nitric acid, if required to bring the sample into solution, should be removed by evaporation of the solution to dryness. Then the residue is extracted with hot dilute hydrochloric acid. Table 1 gives the procedure to be followed for the group separations. The special tests then follow. These tests are carried out by spotting on to a strip of pure filter paper, or by mixing in a depression of a porcelain spotting tile, or in small test-tubes. The special tests given here have been selected with regard to their simplicity, convenience, and accessibility of the materials required. It is not suggested that they are the best tests available for each estimation, but each one has proved quite satisfactory in class work. New tests are frequently appearing, and revisions and replacements may sometimes be found desirable.

The method now described has been used with complete success in the Analytical Laboratories at University College, Cardiff. Students appreciate the speed and accuracy, and are impressed by the neatness of the tests. Furthermore, they are introduced to some of the simpler methods of microchemistry—a distinct advantage for later training. A marked improvement in the students' laboratory technic has resulted. Thus, in spite of the fact that several writers have recently criticized the use of qualitative analysis and especially of spot tests in the teaching of practical chemistry, the author has no hesitation in recommending a scheme such as that now described for the consideration of teachers.

TESTS FOR METALLIC RADICALS

TEST 1—Silver

(*A*) Add a drop of two per cent. aqueous manganous sulfate, a drop of ammonia, and a drop of sodium hydroxide solution to some silver chloride spotted on to a strip of filter paper. There results a black stain, or,

(*B*) Collect a small quantity of the precipitated silver chloride on a filter paper, and pour over a little five per cent. aqueous potassium cyanide solution. Add one drop of a 0.03 per cent. solution of *p*-dimethylaminobenzalrhodamine in acetone and two drops of 2 *N* nitric acid to one drop of the cyanide filtrate in one of the depressions of a spotting tile. A red coloration is produced. A trace of amyl alcohol intensifies the color.

TEST 2—Lead

Collect a small quantity of the crystalline residue on a filter and wash first with dilute sulfuric acid, then with ammonia and with hydrogen peroxide. If the residue is brown, lead is indicated. Wash with water, and add a small portion of the residue to a mixture of solid ammonium chloride, a drop of dilute acetic acid, and a drop of tetramethyldiaminodiphenylmethane solution (0.5 g. of the base and 5 g. of glacial acetic acid dissolved in 100 cc. of alcohol). A bright blue coloration confirms the presence of lead.

TEST 3—Mercury

(*A*) Dissolve some of the residue of mercuric sulfide with the aid of bromine water (saturated) in one of the depressions of a spotting tile. Add a little dilute sulfuric acid and some five per cent. aqueous phenol. Finally, add a drop of a one per cent. alcoholic solution of diphenylcarbazide and carefully neutralize with sodium hydroxide solution. There is obtained a violet-blue coloration, or,

(*B*) Place a drop of the solution (obtained by dissolving mercuric sulfide in bromine water) on a filter paper. Add a drop of five per cent. stannous chloride solution and a drop of aniline. A brownish black stain confirms the presence of mercury.

TEST 4—Copper

Add a drop of the solution to a drop of a two per cent. alcoholic solution of α-benzoin oxime on a filter paper. Expose the paper to ammonia vapor. A green coloration confirms copper.

TEST 5—Bismuth

Dissolve a portion of the residue in dilute hydrochloric acid in a small test-tube. Add excess of a ten per cent. aqueous solution of thiourea. A yellow coloration indicates bismuth.

TEST 6—Cadmium

(*A*) Heat the residue with sodium carbonate on a small piece of porcelain. Mix the residue with a little powdered charcoal and place in a small ignition tube. Then heat the mixture using a Bunsen flame. A metallic cadmium mirror with brown edges of oxide is formed. When the tube is cold, add a small quantity of powdered sulfur, and once again heat the mixture. The metal of the mirror is changed to cadmium sulfide which is orange when hot and yellow when cold, or

(*B*) A recent and very effective test for cadmium proceeds as follows. To a small portion of the nitric acid washings add acetic acid and sodium potassium tartrate solution. Add a small drop of this test solution to a drop of a 0.02 per cent. solution of *p*-nitrobenzenediazoaminoazobenzene in 0.02 *N* potassium hydroxide (made up in ninety per cent. alcohol) on a strip of filter paper. Finally, add a drop of 2 *N* potassium hydroxide. If cadmium is present, there is obtained a pink spot with a darker edge. In the absence of cadmium, a violet spot is obtained.

TEST 7—Arsenic

Reduce a portion of the residue in a test-tube by gently warming with aluminum powder and 2 *N* sodium hydroxide. Half-way down the tube place a plug of cotton wool moistened with lead acetate solution (in order to remove hydrogen sulfide). Place a strip of filter paper moistened with mercuric chloride solution over the mouth of the tube. The paper is colored yellow and finally becomes brown when arsenic is present.

TEST 8—Antimony

Add a small crystal of sodium nitrite to the solution and mix the product with about 0.5 cc. of 0.01 per cent. aqueous rhodamine B. A violet coloration and precipitate indicate antimony.

TEST 9—Tin

Spot a drop of the stannous solution on to a piece of filter paper which has been treated with a saturated solution of cacotheline in water. A violet coloration indicates the presence of tin.

TEST 10—Iron

Dissolve in dilute hydrochloric acid, and add potassium thiocyanate solution. A blood-red coloration indicates iron.

TEST 11—Chromium

Add a drop of dilute hydrochloric acid, then a few drops of 2 *N* sodium hydroxide and sufficient saturated bromine water to oxidize the chromic salt to chromate. Acidify with dilute sulfuric acid, and remove the excess bromine by adding five per cent. aqueous phenol. Finally, add a small drop of a one per cent. alcoholic solution of diphenylcarbazide. A violet coloration develops in the presence of chromium.

TEST 12—Manganese

Dissolve the precipitate in a drop of dilute hydrochloric acid in a small porcelain dish. Mix the manganese solution with a *small* drop of sirupy phosphoric acid, two drops of water, and a little solid potassium periodate. Gently warm. The liquid turns pink owing to the formation of potassium permanganate.

TEST 13—Aluminium

Acidify the alkaline washings, bringing the acidity to approximately 1 *N*. Add an equal volume of 3 *N* ammonium acetate and the same volume of 0.1 per cent. aqueous ammonium aurine tricarboxylate. Finally, make the solution slightly alkaline with a mixed solution of ammonium hydroxide and ammonium carbonate. Aluminium is indicated by a bright red coloration. It is as well to compare the test mixture with a reference solution made up in the same way but containing no aluminium.

TEST 14—Nickel

Treat a drop of the solution with ammonia and one per cent. alcoholic dimethylglyoxime, either on the spotting tile or on a strip of filter paper. A red precipitate indicates nickel.

TEST 15—Cobalt

Treat a drop of the solution with several drops of ethyl alcohol and add a small crystal of potassium thiocyanate. The crystal becomes colored blue when cobalt is present.

TEST 16—Zinc

Boil the solution with excess of thirty per cent. sodium hydroxide solution (if cobalt has already been found, add some hydrogen peroxide as well). Filter. Neutralize the filtrate with hydrochloric acid (use thymol blue, pH = 8.5, as indicator). The precipitate obtained is zinc hydroxide. Filter. Wash the residue once with water, rejecting the washings. Pour over the residue a little dilute sulfuric acid. Mix a drop of the acid filtrate with a trace of 0.5 per cent. copper sulfate solution on a spotting tile, then add a drop of ammonium mercuric thiocyanate solution (30 g. of mercuric chloride and 33 g. of ammonium thiocyanate dissolved in 100 cc. of water). A violet or black crystalline precipitate confirms the presence of zinc.

TEST 17—Calcium

Add five per cent. aqueous potassium ferrocyanide and solid ammonium chloride. A white precipitate of calcium ammonium ferrocyanide results if calcium is present.

TEST 18—Strontium

Spot a drop of the solution on to a filter paper and then add a drop of a fresh 0.1 per cent. aqueous solution of sodium rhodizonate. A reddish brown coloration due to the formation of strontium rhodizonate, disappearing with a drop of dilute hydrochloric acid, is produced. It is important to compare the test spot with a reference spot of the reagent only.

TEST 19—Magnesium

Add a few drops of 0.05 per cent. alcoholic titan yellow solution to the suspension of magnesium hydroxide in alkali. A violet-red precipitate results. The test should be compared with an alkaline solution of titan yellow, which is orange-red.

TEST 20—Potassium

A yellow precipitate of potassium cobaltinitrite is obtained when a freshly prepared aqueous solution of sodium cobaltinitrite is added to the solution made slightly acid with acetic acid.

TEST 21—Sodium

A large excess (eight parts) of zinc uranyl acetate solution is added to one part of the test solution. A pale yellow precipitate (sodium uranyl acetate) indicates sodium.

Zinc uranyl acetate solution:

(*A*)		(*B*)	
Uranyl acetate	10 g.	Zinc acetate	30 g.
Acetic acid (thirty per cent.)	6 g.	Acetic acid (thirty per cent.)	3 g.
Water to	50 cc.	Water to	50 cc.

Mix the warm solutions *A* and *B*. Filter after twenty-four hours. Finally, mix the filtrate with an equal volume of alcohol.

CATALYTIC OXIDATION—A LABORATORY PROCEDURE

LEROY D. JOHNSON

Storer College, Harper's Ferry, West Virginia

THIS JOURNAL has published several articles[1,2] illustrating the rôle of catalysts in organic and inorganic oxidations. The method submitted is a simple procedure based on the catalytic decomposition of hydrogen peroxide by manganese dioxide and the subsequent oxidation of methyl alcohol to formaldehyde. The equations:

$$2H_2O_2 \longrightarrow 2H_2O + O_2$$
$$2CH_3OH + O_2 \longrightarrow 2HCHO + 2H_2O$$

The usual laboratory method of illustrating this oxidation is by using a heated copper spiral as a catalyst and plunging the same into a test-tube or graduate containing a few cc. of methyl alcohol. The odor of formaldehyde is then noticed.

The second procedure is presented as a supplement to the usual method because for the performance the time limit is reduced to a minimum and the materials and apparatus employed are usually available in the ordinary laboratory. The method employed is as follows.

An eight-inch hard glass or pyrex glass test-tube is placed upright in a ring stand and clamped. The bottom of this tube is covered with a one-eight inch layer of manganese dioxide and heated gently with an ordinary Bunsen burner.

Ten cc. of freshly prepared or C.P. methyl alcohol is mixed with fifteen cc. of three per cent. hydrogen peroxide solution. After shaking this latter mixture thoroughly and turning off the Bunsen burner the alcohol-peroxide mixture is added drop by drop by means of a pipet to the eight-inch test-tube.

As soon as a few drops of the alcohol-peroxide mixture strikes the heated manganese dioxide a vigorous reaction takes place, causing a glowing of the dioxide. There immediately is produced the sharp odor of formaldehyde which is made more perceptible by fanning the fumes toward the investigator's nose in the usual fashion.

[1] HAUT, J. CHEM. EDUC., **11**, 575 (1934).
[2] JOHNSON, *ibid.*, **16**, 238 (1939).

To confirm the aldehyde, however—although the odor is sharp enough, the remainder of the alcohol-peroxide may be slowly added until finally all the mixture is added and the vigorous action ceases. Then, the mixture of manganese dioxide, water solution of formaldehyde, and any unchanged methyl alcohol is passed through a filter paper into a clean test-tube. A few cc. of this clear solution suspected of containing the aldehyde are added to ammoniacal silver nitrate (Tollen's reagent). Upon gentle heating the separation of metallic silver takes place—a confirmatory test for the aldehyde.

CORRESPONDENCE

SEMI-MICRO QUALITATIVE ANALYSIS

To the Editor

DEAR SIR:

The semi-micro course in qualitative analysis was first offered at Wayne in the fall of 1937. Semi-micro analysis has several distinct advantages over the macro system. Not the least of these is the interest of the students in the technic used. Working with small quantities, our students develop good habits of careful handling of samples and reagents, as well as learn the value of extreme cleanliness in the care of glassware.

Another distinct advantage is the economy of the course. Filter paper, an item of considerable expense in a qualitative analysis course, is not used. Filtering, the tedious time-consuming and wasteful process in an analysis course, is eliminated. The separator, a new type of electric centrifuge, in a few seconds separates precipitate and filtrate most efficiently. Breakage is minimized and smaller test-tubes (75- and 100-mm. diameter tubes are used), thirty milliliter casseroles, small dropping bottles and beakers also represent a smaller original cost. Since smaller quantities of reagents are used, the saving in chemicals is obvious.

Also an important advantage of semi-micro is the very apparent reduction of obnoxious gases in the laboratory. A few milliliters of solution require also a similar small amount of hydrogen sulfide, still a necessary evil in qualitative analysis. Small individual generators are used with a source material which ceases to react as soon as the applied heat is removed. Precipitation of sulfides is easily and rapidly accomplished with a minimum of hydrogen sulfide escaping into the air. The possible quantities of other gases such as hydrogen chloride, ammonia and nitric acid are also diminished to a very great degree.

Very little new equipment has been necessary for this change. Most of that which has been purchased is of a permanent nature, and glassware replacements are few and inexpensive. During the first semester, one separator of the solid aluminum head type, with spaces for four tubes, and the necessary tubes were purchased. The next year test-tube racks, 50-ml. Erlenmeyers and individual dropping reagent bottles replaced the larger sized bottles. The addition of small monel spatulas, bath-racks, a few spot plates and casseroles have completed, with other equipment used also in other courses, the equipment for each student.

In conclusion, we feel the semi-micro qualitative analysis course is most satisfactory for the teaching of chemical principles and methods of technic. It is most economical. It is interesting and stimulating to both students and teacher.

STATE TEACHERS COLLEGE LOUISE M. WENDT
WAYNE, NEBRASKA

SPECIAL RESEARCH CONFERENCES OF THE CHEMISTRY SECTION OF THE A.A.A.S.

This conference will be held at Gibson Island, Maryland, during June 17th–21st, June 24th–28th, July 8th–12th, July 15th–19th, July 22nd–26th, and July 29th–August 2nd. The meetings will begin at ten o'clock, with one or two formal papers outlining the fields of research, and directing attention to the unsolved problems. It is advisable to make reservations in advance. For reservations, or further information, write to the Director, Neil E. Gordon, Central College, Fayette, Missouri.

A. *Frontiers in Petroleum Chemistry.* C. R. WAGNER, Chairman, June 17th–21st.

B. *Catalysis,* E. C. WILLIAMS, Chairman, June 24th–28th.

C. *Organic High Molecular Weight Type Compounds,* H. L. BENDER, Chairman, July 8th–12th. Program Committee, R. H. KIENLE, S. S. KISTLER, AND H. L. BENDER.

D. *Vitamins,* C. G. KING, Chairman, July 15th–19th. Program Committee, J. W. M. BUNKER, A. D. EMMETT, AND C. G. KING.

E. *Relation of Structure to Physiological Action,* WALTER HARTUNG, Chairman, July 22nd–26th, Program Committee, D. L. TABERN AND WALTER HARTUNG.

F. *Applications of X-Ray and Electron Diffraction,* MAURICE L. HUGGINS, Chairman, July 29th–August 2nd.

HIGH SCHOOL NOTES

ELBERT C. WEAVER[1]

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A STUDY *of* HEALTH MATERIALS *in* HIGH-SCHOOL CHEMISTRY TEXTS

J. O. FRANK AND C. A. DISCHER

State Teachers College, Oshkosh, Wisconsin

TEACHERS colleges are engaged not only in the preparation of teachers but also in the improvement of education in all of its aspects. The high-school course of study is a matter of great interest and the content of subject matter in chemistry courses, as indicated in textbooks, is a subject of careful study by all those who try conscientiously to prepare teachers of chemistry for high schools.

Nearly three decades of study of high-school science teaching has convinced the senior author of this paper that the valuable materials of high-school chemistry may be classified under four heads.

(*1*) *Inspirational Material.*—Such as historical references; stories of discovery and invention; anecdotes relating to the work and accomplishments of the scientists; strange, unusual or unique facts; romantic "human interest" narrations, and so forth.

(*2*) *Factual Material.*—Facts of chemistry which can be applied largely because remembered by individual items, hence things which are largely lifted directly out of the environment and used in texts to illustrate chemical laws or principles. These things enable the average individual to read the papers and magazines, to listen to the radio, to view the movies more intelligently. They also enable the individual to keep in better health, to be more efficient in his daily activities, to receive a better salary because he will be able to carry on his vocation more effectively.

(*3*) *Pure Chemistry.*—The laws, theories, abstract principles, hypotheses, and so forth, which are illustrated as far as possible with concrete things—but which become patterns or plans for mental processes. These are the materials with which new things are created, from which new ideas are evolved, without which progress in quality or quantity cannot be made. In a world of change these are the most solid things of chemistry, the most useful tools with which to meet new situations.

(*4*) *Applications of Chemistry.*—These are usually illustrative materials. They are taken from industry, from the home, from the street. They consist of principles, laws, facts, episodes, in fact, anything which when narrated or explained, will help the individual to understand better the underlying laws of nature which happen to be involved.

Reports on studies of Historical Items in High-School Chemistry Textbooks and on the Content of Health Materials as Related to Chemicals Involved in Cases of Accidental Poisoning in the United States have already been made by the senior author of this paper.

The present paper is in a sense a continuation of a report of studies being carried out by the chemistry department of the State Teachers College at Oshkosh, and which are designed to assist in the improvement of the quality of chemistry textbooks and the high-school courses of study, especially in Wisconsin high schools.

PLACE OF HEALTH MATERIALS IN HIGH-SCHOOL COURSES

The rôle of secondary-school science as a legitimate factor in the maintenance of our national health is unquestioned. Items relating to personal and public health have always been accepted, with some limitations, as legitimate in high-school chemistry courses. It has been quite as proper for the chemistry instructor to deal with the physiological effects of carbon monoxide as with its physical and chemical properties. Likewise, a small number of other items relating to personal or public health have become a part of high-school chemistry and have been accepted without question because of their importance and because en masse they have not added up to a burdensome percentage of the subject matter of the course.

In the last few years, however, teachers, textbook writers, curriculum specialists, and others have noted the appearance of difficulty in connection with this body of materials. Due to changes in our national life, the extension of chemistry into thousands of small industries and so into daily life, the introduction of chemistry as a major factor in warfare, a subject now for some years a part of our everyday thinking, and to many other influences—the body of health materials

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in high-school chemistry has been rapidly growing in size and importance until it now consists of many items, in fact, whole subjects, with which many teachers, though well informed, feel unprepared to deal.

While the newer textbooks are including much more material which must be classified as health material, there is little agreement as to just what items shall be included, nor are any principles of selection apparent. The author's knowledge and interest seem to be the only criteria, upon which selection has been based in many cases. In general, it can be said that those sec-

TABLE 1

The following table illustrates the method used in tabulating the various health items. It was found that all materials could be classified under twelve different headings. In all cases the meaning of each item rather than its wording, determined its classification. All items from all the texts were entered in the table without raising questions of accuracy of statement or desirability of inclusion.

Oxygen	*Book identification number*											
	1	2	3	4	5	6	7	8	9	10	11	12
Necessary for Life	×	×	×	×	×	×	×	×	×			×
Rôle of oxygen:												
As a scavenger reducing animal and vegetable substances to harmless ones		×	×				×	×				
Decay—process of slow oxidation, aided by bacteria		×	×						×	×		
While free oxygen in a compound is being released, germs are oxidized and killed										×		
Spontaneous combustion—slowly oxidizing substances—with poor circulation of air—temperature may rise to the kindling point and result in a fire	×	×	×	×	×		×	×	×		×	×
Care with: hay, grain, coal, oily rags, and so forth	×	×	×	×	×		×		×		×	
To prevent in coal piles put in iron tubes to conduct the heat away from the pile									×			
To prevent in coal piles sprinkle with water	×											
In the body:												
Gotten when air enters the lungs	×	×	×						×	×		
The hemoglobin picks up the oxygen forming oxyhemoglobin										×		
Blood carries from the lungs to all parts of the body	×	×	×		×				×			
The oxyhemoglobin gives up its oxygen to oxidize food, dead tissues, and poisonous products										×		
Source of heat in the body from oxidation of foods and worn out tissue							×					
Oxidation furnishes heat and energy to the body	×	×	×		×				×	×		×
Oxidation in the body slowed down by nitrogen in the air we breathe	×											
This process yields heat, water, carbon dioxide										×		
Carbon dioxide combines with the hemoglobin and is carried, in the dark blood, by the veins to the lungs where it is exhaled										×		
Necessary for purifying the blood, so must have plenty of fresh air						×						
The products of oxidation are carried back to the lungs and there exhaled largely as carbon dioxide and water							×		×			
The lungs have about six times the capacity needed so that we can continue to live, despite lung injury, disease, or thin air										×		
People ascending to great heights										×		
Suffer from thin air										×		
Often troubled with nose bleed and dizziness; due to the air being less dense										×		
In drowning—death is due to lack of oxygen										×		
When "dopey," breathe more oxygen and you will feel better											×	
One breath of oxygen equals five breaths of air												×
Dissolved in water makes the drinking water more palatable	×											
Uses:												
To destroy offensive odors in drinking water	×											
When patients are too weak to breathe air (oxygen tent)												
Asphyxiation treatment								×				×
Mine rescue work	×		×				×	×	×			×
Firemen			×							×		
Divers										×		×
Pneumonia (eases on lungs)	×	×	×	×	×	×	×	×	×	×	×	×
Aviators for high altitudes	×		×	×	×	×	×			×	×	×
As explosive	×											
Water of rivers purified										×		
In baby incubators											×	
In submarines when beneath surface											×	
In tuberculosis, fresh air is supplied for the patient in an effort to kill germs by oxidation											×	
Sources:												
Sodium peroxide—oxygen generator used for oxygen in isolated places									×			
Ozone:												
Is irritating to human beings								×				×
Should not be breathed in quantity											×	
Some scientists insist a layer of ozone high in the atmosphere absorbs rays highly destructive to living cells										×		
Uses:												
Disinfecting agent—kills bacteria								×	×		×	
Deodorizer								×	×	×	×	×
Used in sufficient quantities will destroy bacteria								×				
Purify drinking water	×	×	×	×			×				×	×
Chlorine is used more often than ozone												×
Purify air	×							×			×	×
In tunnels and zoos	×											
In halls								×				
Bleach												×
Now used very little since certain other chemicals employed more conveniently and economically											×	
Not yet successfully adapted for practical uses									×			

SUMMARY

	Book identification number												
	1	2	3	4	5	6	7	8	9	10	11	12	Total[1]
Necessary for life	1	1	1	1	1	1	1	1	1	—	—	1	1
Rôle of	8	7	7	2	4	3	8	2	9	9	2	2	26
Uses and sources	5	1	4	2	3	3	4	4	2	8	—	4	15
Ozone	3	1	5	4	3	3	1	—	4	4	1	5	14
Totals	17	10	17	9	11	10	14	7	16	21	3	12	56

[1] Total number of *different* items relating to each subject.

tors of knowledge lying between chemistry and hygiene, chemistry and biology, chemistry and dietetics, chemistry and physiology, and so forth, have been drawn upon most often. But even when two different authors have gone into the same field there is no marked agreement as to the subject matter treated in the texts they have produced.

It has been the purpose of this study to determine just what health materials are found in the high-school chemistry textbooks in wide use today, to note the degree of agreement and to assemble all the materials presented in all the textbooks for study and evaluation.

METHOD USED IN THIS STUDY

In this study twelve high-school chemistry textbooks were examined and all health items extracted. Ten of the texts are widely used and two are recent publications by well-known authors. For purposes of this study a health item was identified as anything (fact, rule, law, and so forth) a knowledge of which might contribute directly to the maintenance or improvement of individual or public health.

The individual health items were evaluated on basis of their frequency of occurrence in the twelve texts and then combined into an integrated outline representing all the health materials. The complete outline was used as a basis of evaluation of the individual texts. Sections of the outline were used to compare adequacy of treatment of the most important divisions of the subject matter in the various texts. Misstatements of fact, omissions of important facts, disagreements, humorous statements, trends of change, and other items of interest were noted.

SOME THINGS BROUGHT OUT BY THIS STUDY

The older textbooks, written before 1936, are fairly uniform in make up as far as health materials of all kinds are concerned. Books written since 1936 show less uniformity, due largely, but not wholly, to an introduction of units not previously found in high-school chemistry texts.

All the texts examined are in fair agreement in their treatment of the older units of high-school chemistry such as: oxygen, water, carbon monoxide, carbon dioxide, the halogens, and the metals (Part 1, Table 2). There are fifty-five items of this group in eight or more of the texts. But texts are not in agreement in their treatment of the newer items. Only eleven items in foods, enzymes, health and disease, soaps and detergents, sewage and garbage, war gases, explosives, insecticides are found in eight or more of the texts (Part 2, Table 2).

TABLE 2

OUTLINE OF HEALTH MATERIALS AS FOUND IN HIGH-SCHOOL CHEMISTRY TEXTS

PART 1

- Oxygen
  - Rôle of
  - Uses of
  - Sources of
  - Ozone
- Hydrogen
- Water
  - Occurrence of
  - Importance of
  - Impurities in
  - Purification (methods)
  - Uses of
  - Deuterium oxide
- Hydrogen peroxide
- Nitrogen and nitrogen compounds
  - Nitrogen
  - Cyanogen
  - Hydrogen cyanide and the cyanides
  - Nitric acid
  - Nitrogen dioxide
  - Nitrous oxide
  - Ammonia
  - Amino acids
  - Amines
  - Miscellaneous compounds
- Air
  - Composition of
  - Corrective measures for the prevention of bad air
  - Liquid air
  - Synthetic air
- Carbon and carbon compounds
  - Carbon
  - Carbon monoxide
  - Carbon dioxide
  - Hydrocarbons
  - Hydrocarbon derivatives
  - Alcohols
  - Ether
  - Aldehydes
  - Ketones
  - Organic acids
  - Cellulose products
- Halogens
  - General
  - Fluorine
  - Chlorine
  - Bromine
  - Iodine
- Metals and metalloids (also S, P, and Se)
  - Aluminum
  - Antimony
  - Arsenic
  - Barium
  - Bismuth
  - Boron
  - Calcium
  - Copper
  - Gallium
  - Gold
  - Iron
  - Lead
  - Lithium
  - Magnesium
  - Manganese
  - Mercury
  - Phosphorus
  - Potassium
  - Radium
  - Selenium
  - Silver
  - Sodium
  - Sulfur
  - Zinc

TABLE 2 (*Continued*)

PART 2

- Foods
  - General uses of
  - Types of, their sources and uses
    - Carbohydrates
    - Fats and oils
    - Proteins
    - Minerals
    - Vitamins
    - Water
  - Food requirements of man
    - Factors to be considered in diet
    - Suggested diets
    - Reducing diets
  - Chemistry of digestion
    - General description of the digestive process
    - Digestion of the different types of foods
  - Chemical and physical action of foods on the teeth
  - Discussion of specific foods
    - Beverages
    - Bread (and flour)
    - Caramel
    - Dextrin
    - Fats
    - Gelatin
    - Glucose
    - Lactic acid
    - Lactose
    - Mayonnaise
    - Milk
    - Pectin
    - Saccharine
    - Starch
    - Synthetic foods
    - Vegetables
    - Vinegar
  - Treatment of
    - Spoilage
    - Preservation
    - Cooking
    - Processed foods
    - Adulterants
  - Containers and cooking utensils
- Enzymes
- Health and disease
  - Life processes
  - Hormones and internal secretion
  - Metabolism
  - Health
  - Types of disease
  - Diagnosis of disease
  - Treatment of disease and disorders
    - Natural
    - Chemical
      - Anesthetics
      - Antiseptics (germicides, disinfectants)
      - Alkaloids, hypnotics, and drugs
      - Specifics
      - Serums
      - Laxatives
      - Anti-acid preparations
      - Anti-pain compounds
      - Patent medicines
      - Household remedies
      - Synthetic medicines
      - Toilet preparations
      - Pure food and drug laws
      - Grades of chemicals
    - First aid
      - Poisons and antidotes
      - Burns
- Soaps and detergents
- Sewage and garbage
- Penetrating light rays
- Miscellaneous health items
- Safety in construction of buildings and vehicles
- Insulation
- War gases
- Explosives
- Insecticides

TABLE 3

This table gives a summary of the health items found, by units, and the total for each of the various texts. The date of publication of each text is also given.

	Book identification number												
Date of Publication	1 1935	2 1931	3 1931	4 1936	5 1931	6 1938	7 1938	8 1933	9 1939	10 1936	11 1937	12 1933	Total[1]
Oxygen	17	10	17	9	11	10	14	7	16	21	3	12	56
Hydrogen	1	3	6	3	4	3	4	5	4	5	3	3	11
Water	20	20	23	22	10	32	52	30	38	45	13	34	126
Hydrogen peroxide	2	2	4	6	3	4	4	7	×	3	×	8	16
Nitrogen and its compounds	7	3	17	4	6	11	12	10	11	11	11	7	55
Air	9	9	7	12	5	4	16	3	8	9	4	6	42
Carbon and its compounds	83	47	78	49	63	96	84	60	72	80	79	55	361
Halogens	36	18	18	12	23	16	19	17	22	27	3	27	121
Metals and metalloids, also S, P, and Se	66	61	71	57	46	95	79	74	50	100	24	80	384
Foods	79	111	127	44	11	198	84	39	124	139	172	35	712
Enzymes	×	×	×	×	×	4	3	×	2	6	2	3	13
Health and disease	32	4	57	4	8	138	20	3	67	153	177	8	569
Other miscellaneous items	25	8	19	9	8	38	30	10	31	30	39	15	186
Total Items (by books)	377	296	444	231	198	649	421	265	445	629	530	293	2652

[1] These figures show the total number of *different* items in *all* of the texts, not the sum of all the items in all of the texts.

The total number of different health items found in all the twelve texts was 2652, only *two* of these occurring in all twelve texts and only sixty-six occurring in eight or more texts. In the older units, out of 1172 health items, six hundred ninety-four or fifty-nine per cent. occur but once, but in the newer units out of 1498 items 1109, or seventy-four per cent. occur but once. It is evident that lack of agreement in treatment is much greater in the newer units of high-school chemistry.

The average number of health items in the five texts published since August, 1936, is 78.6 per cent. greater than the average for the seven texts published prior to August, 1936. Part of this is due to the larger size of the newer books. The seven books published prior to August, 1936, averaged 14,000 square inches of printed matter. The five published since August, 1936, averaged 17,000 square inches of printed matter, a gain of 35.7 per cent.

The new materials introduced in the later texts are chosen from the fields which lie between chemistry and biology, chemistry and hygiene, chemistry and physiology, with each text showing a definite trend toward one of those fields. There is also a definite tendency to include smaller units which have been of particular interest to the authors, or which have recently been of deep public interest. There is, of course, little agreement in the treatment given these items. Table 4 gives a list of examples of such treatment.

TABLE 4

	Number of texts treating	*Total number of items*	*Number of items in:* *Highest*	*Next*	*Third text*
Patent medicines	4	30	20	5	3
First aid	5	52	29	18	2
Toilet preparations	3	50	48	1	1
War gases	3	23 out of 26 items in two texts			
Sewage and garbage disposal	4	28	17	7	4

But not all new items occur in one or two texts only. For instance: hormones are discussed in six texts in a total of seventy-seven items. The three texts richest in these items have twenty-eight, twenty-four, and twenty items, respectively.

The general trend is to place less emphasis on chemical laws, principles, theories, and the quantitative aspects of the subject, and to give more space to presentation of specific facts—especially things of everyday interest. War gases, chemistry of dry cleaning, enzymes, and toilet preparations, are topics receiving increased attention.

The newer texts contain many more items relating to foods. The average number in the older texts is seventy. The average in the newer texts is one hundred fifty-seven, an increase of nearly two hundred twenty-five per cent.

All texts, without exception, fail to deal adequately with the forty or more chemicals which are factors in 40,000 cases of accidental poisoning and 7000 deaths annually in the United States.[2] But the newer texts, (1938 and 1939) have about forty per cent. more material of this kind than those published prior to 1936.

One text published prior to 1936 was very much better than any of the other texts of its time in the total number of health materials, and especially in its treatment of the list of chemicals causing accidental poisoning.

In general, textbook authors have tried to avoid definite statements on controversial subjects. In several cases exact statements from books of twenty or thirty years ago are found in texts of this decade though it is now known that these statements are incorrect. Authors of two or three of the newer texts have gone to the trouble to find out the facts and have clearly and boldly stated them.

A few books have been published as revisions, though it has been impossible to find any evidence of revision. These books are just reprints under a later date.

There were a number of cases of confusion of terms. Such terms as *germicide*, *disinfectant*, and *antiseptic* were used carelessly. In some cases the author did not say what he meant to say.

There were omissions of important facts. Typical is one book which has a long account of radium and its discovery but never mentions its use in medicine.

Misstatements of facts occur in some texts. "Large quantities of petroleum ether are used in hospitals,"

[2] FRANK, J. CHEM. EDUC., **15**, 532–6 (1938).

"Alum is a constituent of one type of baking powder," and "The Mesabi Range lies south of Lake Superior" are typical of such statements.

There were a number of disagreements in statements of facts such as the poisonous nature of arsenic, the per cent. of carbon monoxide necessary to cause death, the per cent. of NaClO in Dakin's solution, the per cent. of NaI in iodized salt, and so forth (about sixty in all).

A few cases of carelessness in directions for demonstration of student experiments were found. One book gives students directions for rubbing a solution of mercuric chloride on a penny (the very first experiment), but never mentions the poisonous nature of this solution.

Some of the books use tables and charts to present the facts regarding the carbohydrate, fat, protein, or vitamin content of various foods, poisons and antidotes, antiseptics, hormones, and so forth, while others include all information of this kind in the text.

SUMMARY AND RECOMMENDATIONS

(1) The increasing attention given health materials, by the more recent textbooks, is but one of several indications of the very real need for such materials.

Teachers have voiced this need repeatedly during the past few years. There are many evidences that changing American life is making the need for practical health materials greater each year. Many of these materials are unquestionably chemical in nature, and high-school chemistry cannot dodge the responsibility of dealing with them.

(2) In the attempt to meet these new needs, textbook authors have begun to include new fields which have heretofore been considered related to chemistry, but more closely related to other fields, such as hygiene, physiology, sanitation, and medicine. There is little agreement as to what new fields ought to be included and real chemistry is tending to become a smaller and smaller part of the textbook content.

(3) There is a very real need for careful study of health materials, and a practical list of items which rightly belong in chemistry texts should be determined. While teachers should make as much of this field available to pupils as possible, many of the materials can be dealt with through supplementary teaching, and they should not be permitted to crowd out or displace the body of principles, laws, and factual materials which make up the true science of chemistry.

CONCOMITANT PROBLEMS THAT ARISE *with the* PRESENTATION *of the* SUBJECT MATTER *in* SECONDARY CHEMISTRY

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THE teaching of chemistry at the high-school level cannot remain static. The development of the study of education has tended to show that a knowledge of the subject matter alone is not enough. Powers states that the investigations in the field of science teaching that have been carried forward during the past fifteen years have been "concerned (1) with the evaluation of subject matter and methods used in current practices in teaching, (2) with the continuous revision of subject matter and methods, and (3) with the study of the learning process" (*1*). The reverberations of these studies have not passed over the field of high-school chemistry.

In a recent discussion of what the high-school science teacher should know the following list was given (*2*).

(1) Knowledge of science as a general field.
(2) Some degree of specialization in one field.
(3) Knowledge developed in professional education.
(4) Knowledge of the professional literature of the craft.
(5) Knowledge of the science textbooks that have been developed for use in the secondary field.
(6) Working knowledge of the equipment needed.
(7) Acquaintance with familiar applications of the science taught.
(8) Sound knowledge of current literature.

From the foregoing statements it can be assumed that the qualifications of those who propose to teach are constantly being raised.

With all of the factors of teacher-education in mind the present study has been developed on the grounds of its possible contributions to educational knowledge. By objective means a significant list of problems that accompany the teaching of the subject matter in high-school chemistry was developed. This list, as determined, can serve as a basis of a syllabus to be used as

follows: (*a*) in the organization of a course of study for the training of teachers of secondary chemistry, the course to be applicable to either prospective or in-service teachers; (*b*), in the possible outlining of a professional textbook on the general subject of the teaching of high-school chemistry.

To obtain the list of problems reported approximately four hundred note cards were obtained from the issues of the JOURNAL OF CHEMICAL EDUCATION (*3*); and *School Science and Mathematics* (*4*) that have been published since September, 1920 through June, 1938. A similar method is also mentioned by J. O. Frank (*5*). The JOURNAL OF CHEMICAL EDUCATION began publication in January, 1924; whereas *School Science and Mathematics* has been published continuously throughout the entire period covered.

Concerning each article the note cards contained the following information: (1) the author's name, (2) the title of the article, (3) the publication source with the volume and date of issuance together with the page references, and (4) notations as to the general information relative to the teaching of chemistry at the secondary level.

It was found that the articles could be classified into five general divisions or areas. Each area was determined to be a comprehensive and significant aspect of the teaching problems of high-school chemistry. Each of the areas will be discussed at length as this report develops. Each area was further divided into its elements or subdivisions. These were ranked according to their frequency and are discussed in that order.

The limitations of this procedure for obtaining a list of the concomitant problems are as follows.

(1) The total number of cards included may not represent all the articles that could have been included. They represent a personal selection.

(2) The selection of the general areas to form the major divisions and the further selection of the subdivisions may be questioned. Here again personal opinion is a determining factor.

(3) As indicated by the title, the articles selected referred only to chemistry instruction at the secondary level.

PROBLEMS THAT ARISE IN THE AREA OF COURSE ORGANIZATION

The tabulation of the cards relating to the area of course organization revealed that their subjects centered around eight subdivisions. These divisions listed in order of their rank were as follows.

(*A*) Proposed Bases for Course Reorganization.
(*B*) The Aims and Objectives of High-School Chemistry.
(*C*) The Articulation of College and High-School Chemistry.
(*D*) The Selection and Choosing of Materials of Instruction (Textbooks, Manuals, and so forth).
(*E*) The Determination of Course Content.
(*F*) The Application of the Findings of Education and Psychology.
(*G*) Curriculum Problems.
(*H*) The Trends in High-School Chemistry.

Nearly one-half of all the cards collected relative to the study were in this area. The large number of articles published relative to the determination of items relating to the broader aspects of the chemistry course would seem to indicate an unusual amount of critical thinking being done along philosophical lines, especially during the past few years.

A GENERAL DISCUSSION OF EACH OF THE SUBDIVISIONS IN THE AREA OF COURSE ORGANIZATION

(*A*) *Proposed Bases of Course Reorganization.*—A review of the articles written on this subject indicates that there is a general dissatisfaction among teachers with the traditional college preparatory chemistry course. It also indicates that despite the restrictions of the accrediting agencies some experimentation has taken place.

The following bases for course reorganization have either been proposed or put into actual practice:

(1) That the high-school chemistry course be reorganized on a pandemic or cultural basis. (The majority of these pandemic proposals refer to courses based on the practical applications of chemistry. Others lean more toward building the course on chemical fundamentals. There were all shades of interpretation for the terms pandemic or cultural.)
(2) That special courses be organized for high-school chemistry. (These proposals usually reflect local conditions. They refer to industrial chemistry, commercial chemistry, the chemistry of cosmetics, household chemistry or other similar titles.)
(3) That advanced courses in chemistry be organized. (These proposals usually come from teachers in the larger high schools. A second-year chemistry course is suggested to be organized about elementary qualitative or quantitative analysis.)
(4) That a course on minimum essentials be organized. (These proposals lean toward a course of chemistry fundamentals. This tends to eliminate the practical aspects.)
(5) The recommendation of separate courses for boys and girls. (Throughout the period covered by the study this reorganization of high-school chemistry is suggested. The basis for this proposal arises from the possible differences in the needs of boys and girls.)

Other course reorganization proposals are listed as follows: (1) courses organized on basic chemical fundamentals only; (2) on the project basis; (3) two separate courses (college and non-college preparatory); (4) courses suited for both college and non-college pupils; (5) courses emphasizing the unit organization; (6) courses planned on the contract basis; (7) courses emphasizing the historical aspects of chemistry; and (8) a course designed for consumers.

As can be observed from the foregoing discussion the problems that arise with the organization of the high-school chemistry course reflect a variety of educational purposes. There is no general agreement other than those imposed by the college entrance requirements.

(*B*) *Aims and Objectives in Course Organization.*—There has been a constant re-checking of the aims and objectives of secondary chemistry. The problems on the aims and objectives in course organization center around the setting up of and adjustment to the following ideas:

(1) The adaptation of high-school chemistry to the everyday life of the pupil.
(2) The adaptation of high-school chemistry to social needs of the pupil.
(3) The development of a "cultural" chemistry course.
(4) Studies evaluating the present aims and objectives.
(5) Statements of course objectives in terms of the basic principles and fundamentals of chemistry.

The problems that arise in the selection of aims and objectives show a definite trend in the attempt to make the teaching of high-school chemistry more meaningful to the pupils who elect to take it. There is, however, a difference of opinion as just what is the basis on which to build the pandemic or cultural courses.

(*C*) *The Articulation of High-School and College Chemistry.*—Throughout the entire period covered by the present study there has been a sustained interest in the problems involved. The problems center around the following categories:

(1) Studies measuring the degree of success obtained in college by those (*a*) who have had and (*b*) those who have not had high-school chemistry.
(2) Proposed readjustments in the high-school course to articulate more closely with the college work.
(3) Examinations of the requirements in college chemistry.
(4) Criticisms of the teaching of high-school chemistry.
(5) The overlapping of college and high-school chemistry.
(6) Statements of the responsibilities of the colleges in relation to these problems.

The material presented in this connection is both conflicting and confusing. The possible solution lies in the direction of redefining the high-school program in terms of a general education rather than for college preparation; at the same time the colleges adopting methods of determining qualifications for admission other than the following of certain prescribed high-school courses.

(*D*) *The Selection and Choosing of the Materials of Instruction.*—The average teacher has neither the time nor the ability to organize his course of instruction in its entirety. As a consequence, he relies very largely on published materials, such as textbooks, laboratory manuals, and workbooks. The articles comprising this group show a process of evaluating this type of material.

(1) Problems of selecting or evaluating a textbook.
(2) Studies of the contents of textbooks.
(3) Studies of the materials in laboratory manuals.
(4) Special aid material, such as: mathematical aids, special texts, pamphlets, charts, and so forth.
(5) Other suggestions include, measuring the contents of instructional materials in terms of the amount of biochemistry, organic, historical material, and so forth, included.

This constant evaluation of instructional materials has no doubt brought about desirable improvements in the materials of instruction.

(*E*) *The Determination of Course Content.*—The problems that come within the scope of this topic are entirely dependent upon what the individual teacher decides with reference to pupils taught, and the extent to which the chemistry course is to be developed. Our list of problems for this division includes:

(1) The place of qualitative and quantitative analysis in high-school chemistry.
(2) How far should the inclusion of the new findings in science go in high-school chemistry?
(3) The need for studies of the difficulties of certain subject matter in the high-school course.
(4) Such questions as: the quantity of biochemistry and of organic chemistry to be taught; what shall be the relative amounts of theoretical and practical chemistry; and the adaptation of course content to local needs.

A perusal of the above list will show how dependent the choice of the course content is on the broader philosophical aspects of course organization.

(*F*) *The Application of the Findings of Education and Pyschology.*—The study of chemistry has felt the impact of the recent development of studies of education and psychology. More and more the articles refer to the implications of the findings in those fields for the teaching of chemistry. In general they center around (1) educational modifications of teaching concepts and (2) recognition of the pyschological factors that influence the teaching process. A third should be noted at this point, that is, the recognition of individual differences and the teaching adjustments for them.

(*G*) *Curriculum Problems.*—The curriculum problems of high-school chemistry as shown by a study of the periodical articles apparently concentrate at two points. The first is, how can the course be made to articulate in a better fashion with the other subjects in the school program? The second is that of defining the place that chemistry has in the secondary-school program. In other words, shall it be taught as a separate subject, or shall it become fused in a more functional program?

(*H*) *The Trends in High-School Chemistry.*—A few of the articles that were included in the area of course organization were concerned with trends in the field of high-school chemistry. Such articles are valuable for teachers inasmuch as they tend to give a more comprehensive picture of what is happening. They put together the bits of the puzzle and give a more complete picture.

SUMMARY OF THE SECTION ON COURSE ORGANIZATION

A review of the problems found in this area may be summarized in the following manner.

From the problems of course reorganization it was indicated that no general agreement has been reached as to the exact basis on which to build high-school chemistry. There is a tendency to develop them for cultural purposes. Just how this is to be done remains an unsolved question. Perhaps the most clearly defined bases are those that tend toward the practical applications and others that lean toward the fundamental scientific concepts in chemistry.

As to the aims and objectives of course organization, there can be no doubt after surveying the literature that the emphasis is away from those established by the college entrance requirements toward newer objectives

pointed to the development of the whole personality of the individual regardless of future educational plans.

The problems relative to the articulation of college and high-school chemistry have shown how definitely the high-school course of previous years and particularly that of chemistry has been set up merely as a stepping stone to higher education. Recent work has led to a reconsideration of high-school objectives and will eventually lead to the adoption of different entrance practices by the institutions of higher learning.

The selection and choosing of the materials of instruction will be basically affected by the predominate philosophy or purpose of the high school. With a shift of course emphasis and an honest realization of what can be actually accomplished by the high-school pupil new materials will be forthcoming. The articles in this division indicate that we are in a transitional stage. The materials of instruction show the influence of the past, the indecision of the present, and glimpses as to future possibilities.

The determination of course content like the choice of instructional materials reveals problems born out of doubt. The abundance of possible content in the field of chemistry makes the selection of subject matter for the secondary level difficult. Perhaps the most evident tendency at the present time is that of including too much content.

Evidence is at hand that the educational aspects of chemistry teaching and the application of psychological concepts are being felt in high-school chemistry course organization. The organization of materials on the unit plan and the inclusion of learning devices indicate wholesome influences. Perhaps the most clear-cut evidence is in the recognition of individual differences of pupils.

The major curriculum problem in secondary chemistry is the coördination of the subject with other materials in the school program. Still another problem looms not far distant; that is, will chemistry keep its identity as a separate subject or become merged or fused as a part of a generalized science program?

The reference to trends bears no problematic situations, but it does afford a general overview of the problems of course organization as a whole.

THE PROBLEMS THAT ARISE IN THE AREA OF COURSE ORGANIZATION STATED AS QUESTIONS[1]

(*A*) Proposed Course Reorganizations

(1) How much "consumer science" can be taught in high-school chemistry?
(2) What is the value of the unit-method organization?
(3) How shall the pandemic course be organized?
(4) What are the basic principles of chemistry?
(5) Shall the development of course be differentiated for boys and girls in high-school chemistry?
(6) What minimum standards of subject matter should be set up?
(7) What are the new courses in high-school chemistry?
(8) What do we mean by functional or utilitarian courses?
(9) What is a general education? How can chemistry contribute?
(10) Shall special courses be encouraged, or shall the emphasis be placed on a single all-round course?
(11) Shall the chemistry course be extended one more year?
(12) Is it possible to organize a single chemistry course to serve the purposes of both the non-college and the college preparatory pupils? Or, shall two separate courses be organized?
(13) How much chemical history shall be included in the high-school course?
(14) Will chemistry lose its identity as a separate course and become fused or merged into a generalized science program?

(*B*) Problems Related to Aims and Objectives

(1) How necessary is chemistry in the high-school curriculum?
(2) Does chemistry need to be more socialized?
(3) What are the social values of high-school chemistry?
(4) What are the objectives of the present course? Is it meeting the needs of the pupils?
(5) How can the high-school chemistry course better serve the purpose of a "liberal" education?
(6) What chemistry should every adult American know?
(7) What is cultural chemistry?

(*C*) Problems in the Articulation of College and High-School Chemistry

(1) How can we get a closer relationship between college and high-school chemistry?
(2) How can colleges or universities recognize proficiency in chemistry?
(3) How can the parallelism between high-school and college chemistry best be overcome?
(4) What is the contribution of high-school chemistry toward success in the college chemistry course?

(*D*) Problems in the Selection and Choice of Materials of Instruction

(1) How, when, and where grade laboratory notebooks?
(2) How closely do the aims and content of laboratory manuals correlate?
(3) How much history; organic chemistry; or mathematics should be included in an elementary textbook?
(4) What should be the basis of the teacher's selection of a high-school chemistry textbook?
(5) What special teaching aids does the instructor need?
(6) Why use textbooks in elementary chemistry?

(*E*) Problems Arising in the Determination of Course Content

(1) Are we wasting our chemistry students' time with factual materials?
(2) How far should the teacher develop the theories of chemistry?
(3) What material shall we select for the elementary course?
(4) Do we know the relative difficulty of the topics we are teaching in elementary chemistry?
(5) How much of the special chemical fields should we try to cover?
(6) How much shall we adapt the course to fit local needs?
(7) What is the place of qualitative and quantitative analysis in high-school chemistry?

(*F*) Problems in the Application of the Findings of Education and Psychology

(1) How can we meet individual differences in high-school chemistry?

[1] As nearly as possible the summary problems for each area shall be stated as questions and in as many instances as practical taken from the titles of the various articles reviewed for this study.

(2) Shall we segregate the pupils according to their abilities? In the classroom? In the laboratory?
(3) What shall be the basis of segregation?
(4) How can we apply psychology to chemical education?
(5) What are the educational values of high-school chemistry?
(6) Will a study of pupil errors in chemistry aid in the determination of our educational emphasis?
(7) What were some of the educational and psychological misconceptions in the early teaching of high-school chemistry?

(*G*) Curriculum Problems

(1) Can chemistry become a part of a science sequence?
(2) What is the place of chemistry in the high-school program?
(3) Can chemistry be taught as a related subject?
(4) What are some of the difficulties of curriculum construction in high-school chemistry?

(*H*) Trends in High-School Chemistry

(1) What are the trends in high-school chemistry organization?
(2) What are the implications of these trends?

PROBLEMS THAT ARISE IN THE AREA OF COURSE PRESENTATION

The problems that are discussed in this area are among the most significant in the development of the present study. Those that were discussed in Area I were important but bordered on an area where perhaps the ordinary teacher may not have a great deal of personal control. Those to be discussed at this point are directly related to what the teacher does in the classroom and laboratory. They are directly associated with the learning process.

James Harvey Robinson in discussing education had this to say about the learning process (*6*).

> "There is already a vast literature of education, most of it surprisingly dull and pointless. A great part of it has to do with vague ideas of what should be learned in order to mold character, or get on in the world, or become good men and women. Then there is much attention devoted to teaching and school administration. All this is easy compared with attempts to penetrate the mystery of learning. This comes and goes in mysterious ways and eludes calculation. Teaching may hasten learning; it may also block it or kill it outright, or sometimes just render it comatose."

In commenting on this subtle process of learning, another writer has referred to it as the "Miracle of Learning" (*7*).

All the items discussed in this area are related to the learning process and the chemistry teacher's especial contributions. There are four general subdivisions of the area. They relate to (1) classroom problems, (2) laboratory problems, (3) problems of general method, and (4) the controversial discussions around the relative merits of individual laboratory exercises and demonstration experiments.

GENERAL DISCUSSIONS OF THE SUBDIVISIONS IN AREA II

(*A*) *Problems That Arise in the Classroom.*—Over fifty of the articles in Area II dealt with problems that arise in the classroom. Listed according to their frequency rank they are as follows.

(1) Problems involving the mathematics of chemistry.
(2) Problems involving demonstration experiments.
(3) Problems arising with the presentation of theories in chemistry.
(4) Problems arising with the teaching of formulas, equations, and chemical nomenclature.
(5) The problems of science errors in teaching.
(6) Problems arising with the development of desirable study habits in pupils.
(7) Problems of overcoming poor teaching conditions.
(8) Problems around the improvement of lesson plans.
(9) Problems of helping the beginning pupil.
(10) Problems relating to the precedence of laboratory and classroom recitation.
(11) A miscellaneous group of problems relating to diagnostic teaching, analysis problems, and the physical arrangement of the classroom.

The foregoing gives a list of problems that may reach outside the chemistry class situation. The list of questions at the end of this section will enlarge the concept and range of the classroom problems.

(*B*) *Problems That Arise in the Laboratory.*—In addition to the problems of classroom teaching the chemistry teacher has the extra problems that come from laboratory instruction. In the articles written by persons engaged in the teaching of the subject the following problems were listed.

(1) Problems of developing the scientific method and the scientific attitude in the laboratory.
(2) Problems in developing student apparatus for laboratory use.
(3) Problems arising in developing minimum equipment lists.
(4) Problems of maintaining laboratory work on limited budgets.
(5) Problems in the handling and care of materials and apparatus.
(6) Problems concerning the functional value of the laboratory.
(7) Problems of student segregation in the laboratory.
(8) Problems of projects in the laboratory.

That the laboratory is no longer an accessory to the teaching process, but an important agency in the process, is evidenced from the problems stated. The desire for more effective teaching is a basic reason for the intensive study of what should be done in the laboratory.

(*C*) *Problems of General Method.*—The problems of general method may be grouped into two general divisions. The first is relative to studies of the effectiveness of various methods of instruction. The second is a list of outlines for the uses of various methods. As to the point of popularity there is equal opinion on contract and unit methods (based on a number of articles). The project method was popular during the early part of the period covered by the study, but at the present time projects tend to be regulated to the field of course enrichment. The studies do not show any outstanding superiority of any of the general methods. It must be assumed, then, that they are experimental processes and suitable devices for teacher innovation in teaching. It is not the purpose of the present discussion to carry reference to the problems of general method any further than to point out that there are

certain changes in them being adapted to the teaching of chemistry at the secondary level.

(*D*) *Laboratory versus Demonstration Problems.*—This is designated as a subdivision although it crosses both classroom and laboratory problems. However, it has been an important and controversial point of discussion in the field of chemistry and in the field of science education as a whole. The articles relating to this field become more meaningful when they are studied relative to their chronological appearance. The early articles revealed that the general laboratory practices were not securing the results sought and gave almost unanimous support to the idea of all-demonstration work in high-school chemistry classes. This view was followed by a period of evaluating both the individual laboratory method and the demonstration technic. At the present time merit is recognized in both procedures. As a consequence there probably will be developed a more intelligently planned laboratory course in addition to improved demonstrations.

SUMMARY OF AREA II IN QUESTION FORM

(*A*) Classroom Problems

(1) How can diagnostic teaching be done?
(2) What is a good lecture-demonstration experiment?
(3) What are good working models?
(4) What items in the elementary course are best demonstrated?
(5) What are some good, simple demonstrations that will illustrate chemical theories and fundamentals?
(6) Why demonstrate experiments?
(7) What will the lecture-demonstration not accomplish?
(8) Should the pupils write up lecture-demonstration experiments?
(9) What are the educational and psychological characteristics of the lecture-demonstration?
(10) What are good methods of teaching oxidation and reduction equations?
(11) What methods are to be used in the teaching of writing equations?
(12) What can we expect from the high-school student in formula and equation writing?
(13) How can we help the beginner to grasp formulas and chemical nomenclature?
(14) How have the names of the elements been derived?
(15) How can the pupil's study habits be improved?
(16) What are the study methods of our pupils?
(17) How can we use student topics and reports?
(18) How can we handle large classes?
(19) How can recitation be improved?
(20) How can lesson plans be improved?
(21) What type of classroom is best?
(22) How can we best introduce the pupil to the study of chemistry?
(23) How can we aid the beginner?
(24) Where can the teacher obtain information of the newer discoveries?
(25) What are the difficulties in teaching definitions?
(26) What aids in teaching theoretical concepts?
(27) How can the electronic theory be used in teaching valence?
(28) What are modern methods in teaching chemistry?
(29) How can the periodic table be used in teaching?
(30) How can science errors be avoided in teaching?
(31) How are graphs used in teaching chemistry?
(32) What are good methods in presenting and teaching the metric system?
(33) What arithmetic is needed in first-year chemistry?
(34) Can mathematics be used to clarify chemical concepts?
(35) Which are the essential and which are the supplementary calculations in chemistry?
(36) How can we teach ratio and proportion?
(37) What is the order of precedence in laboratory and recitation work?

(*B*) Laboratory Problems

(1) What is the function of the laboratory?
(2) Should the laboratory be used as the center of instruction?
(3) How can scientific ability be improved in the laboratory?
(4) Does the laboratory work belong in high-school chemistry?
(5) What are the fundamentals of laboratory instruction?
(6) How can we improve the efficiency of laboratory work?
(7) Shall we segregate pupils of different abilities in the laboratory?
(8) What methods should be used in the laboratory?
(9) Shall we precede laboratory work with a demonstration in laboratory technic?
(10) How can the laboratory be maintained on a reduced budget?
(11) What are some economies that can be maintained in the laboratory?
(12) What is the minimum equipment for a high-school laboratory?
(13) What kind of balances should be used in high-school chemistry?
(14) What are the safety devices needed in the laboratory?
(15) What are some good methods of handling materials and apparatus in the laboratory?
(16) What are good project-experiments for the laboratory?
(17) What are some improvements that can be made in the apparatus designed for student work?
(18) What are the achievements of the pupil desired in the laboratory?

(*C*) Problems of General Method

(1) What is the relative value of each general method?
(2) What is the unit-method of teaching? Evaluate it.
(3) How far can we go in teaching by the project method?
(4) What is the contract plan of teaching?
(5) Is there another method to be used?

(*D*) Laboratory versus Demonstration Problems

(1) What do the research studies show about this controversy?
(2) For what type of learning is each method best suited?
(3) What price laboratory instruction?
(4) How can the technic of demonstrating be improved?
(5) How can individual laboratory instruction be improved?
(6) What is the history of this controversy?
(7) What is the latest thought on this problem?

PROBLEMS THAT ARISE IN THE AREA OF COURSE ENRICHMENT

Modern teaching has extended its activities beyond the pages of a single textbook. The activity movement in education has encouraged the use of all sorts of devices as aids to the learning process.

The chemistry teacher of today takes advantage of all sorts of aids to enrich the subject program. The motives for the use of such devices may be varied but the "humanizing" effect that it has on the teaching process and on the making of life situations in the classroom cannot be construed otherwise than to have a wholesome effect on the teaching procedure.

Many of these aids bring a closer relationship between the school and the community it serves. In a number of the articles reviewed the teachers stated that these extra teaching materials were developed with the idea of selling chemistry to the public at large.

By far the largest single justification for course enrichment is to capitalize on pupil interest. When this is done in a wholesome manner there can be no doubt as to its ultimate beneficial effect on both teacher and pupil.

WHAT ARE THE DEVICES USED FOR COURSE ENRICHMENT?

A tabulation of the devices used for course enrichment showed that twenty-three different items were used. The list follows, arranged in order of their approximate frequency.

(1) Projects.
(2) Chemistry clubs.
(3) Chemistry exhibits.
(4) Stunts and novel experiments.
(5) Open-house programs.
(6) Articles on unusual chemistry topics.
(7) Special qualitative and quantitative experiments.
(8) Student research.
(9) Working models.
(10) Posters.
(11) Use of pamphlet literature.
(12) Bulletin boards.
(13) Assembly programs.
(14) The science fair.
(15) Chemistry scrapbooks.
(16) Industrial motion pictures.
(17) Studying the names of the elements.
(18) Using chemical history.
(19) Vocational guidance programs.
(20) Visual education.
(21) Safety education.
(22) The chemistry library.
(23) Inspection trips.

Any one of the foregoing topics could be well used as a basis for a general discussion. To make the extra work have meaning, time and thought must be given to it in order that its educational values will be developed.

WHY DO TEACHERS USE THESE DEVICES?

A survey of the periodical cards indicates that teachers use the enrichment devices for a wide variety of reasons. Broadly speaking they are using them to solve certain teaching problems. Below are listed some of the reasons given for projects and other devices described.

(1) To fill out at the end of the course.
(2) To make the course more functional.
(3) To enlarge chemical concepts.
(4) To vary teaching procedure.
(5) To aid the individual; *i. e.*, sustain interest.
(6) To coöperate with the general school program.
(7) To link up the course with the outside world.
(8) As supplementary teaching.
(9) To aid in social development.
(10) To avoid too much specialization.
(11) For course motivation.
(12) To recognize local conditions.
(13) To improve the work of the second semester.
(14) To recapitulate on chemical principles.
(15) To give pupils a notion of research.
(16) To supplement term reports or essays.
(17) For use of after-school time.

PROBLEMS OF AREA III SUMMARIZED

(1) How can we duplicate some of the classical experiments of chemistry?
(2) What models of certain chemical plants can we make?
(3) What avenue of special interest does the pupil have?
(4) What are some easy projects to do?
(5) What are the educational values of chemistry projects?
(6) Who should do projects? Only the better chemistry students?
(7) How can the project be related to local industries?
(8) Can projects bring in ideas not studied in class work?
(9) Shall they be individual or group projects?
(10) What is a good class project?
(11) What about student projects as part of consumer education?
(12) Can projects illustrate chemical principles?
(13) What method shall be used in developing the project?
(14) Shall the pupil report on the project? To the teacher? To the class?
(15) What are the sources of project material? Teacher list? Textbook? A cumulative list? Reference books?
(16) How can we use the pamphlets issued by industries, the government, and other sources?
(17) What are some spectacular experiments?
(18) How can we use chemical magic?
(19) To what use shall the spectacular experiments be put?
(20) What is student research?
(21) How is student research different from projects?
(22) Should the chemistry club program correlate with the regular course of study?
(23) What can the chemistry club do?
(24) Is the high-school chemistry club worth-while?
(25) What are the characteristics of a live chemistry club?
(26) What are some activities suggested for the chemistry club?
(27) Why make chemistry posters?
(28) How can the chemistry bulletin board be a teaching device?
(29) Should the poster be a regular assignment?
(30) Is the chemistry exhibit a supplementary teaching device?
(31) Shall we use the commercial exhibit materials?
(32) How can we use the chemical exhibit as a project review?
(33) How can chemistry exhibits be used in the small laboratory?
(34) How can chemistry be made to contribute to the school assembly?
(35) What part can chemistry play in an open-house program?
(36) How can interest be stimulated in chemistry?
(37) Is there value in a chemistry scrapbook?
(38) How shall we use industrial motion pictures?
(39) Does the industrial motion picture meet the standards of visual education?
(40) What are some unusual chemistry topics?
(41) What's in a name? (A study of the chemical elements.)
(42) How can the history of chemistry be used to enrich the course?
(43) What is the place of the chemistry teacher in the vocational guidance program?
(44) What procedure should be used in vocational guidance?
(45) What is the minimum equipment for visual education?
(46) Name the different kinds of visual equipment.
(47) What are the opportunities for safety education in chemistry instruction?
(48) How can qualitative and quantitative analysis be used for course enrichment?
(49) What are some readable general references on chemistry?

(50) What is the teacher's part in building a chemical library?
(51) Where can a good chemistry book list be obtained?
(52) Why ask for extensive outside reading?
(53) How can chemistry be sold to the community?
(54) How can the most value be received from chemical inspection trips?
(55) What are the characteristics of a well-planned inspection trip?

PROBLEMS THAT ARISE IN THE AREA OF COURSE EVALUATION

During the past few years the high-school testing program has been subjected to close study. The development of standardized, objective tests has led to an improved program of evaluation. It is of interest to note the shift of emphasis that has taken place in the testing program: from the essay type to the new-type examination; from the emphasis on factual information to attempts to measure the more elusive factors of attitudes, types of thinking, and uses of the scientific method. In the case of chemistry instruction, the last statement can be interpreted to refer to the attempts to measure chemical facts and learnings in terms of the scientific attitude and method.

New uses have also been found for the testing program. Tests are no longer used to determine course grades only but are also used as teaching devices. They are used for diagnostic purposes and for measuring comparative achievement. Attempts are also being made to develop devices to measure and evaluate other aspects of the chemistry program. Tests are now designed to measure laboratory technic and to ascertain the pupil's knowledge of other basic skills.

In general, tests may be used by the alert teacher for the following purposes: (1) to get a total picture of the pupil (the pupil's general intelligence, knowledge of mathematics or reading ability), (2) to measure and diagnose the pupil's progress through the presentation of the course of instruction, and (3) to measure the pupil's general achievement at the completion of the course of study. By these means the teacher has a complete, continuous pattern of pupil growth, not an occasional sporadic sampling of the pupil's ability to repeat factual information.

For convenience of discussion the periodical articles relating to the evaluation program will be discussed in groups. This grouping is purely arbitrary but eliminates discussion on twenty-nine separate titles.

DISCUSSION ON VARIOUS PHASES OF THE EVALUATION PROGRAM

(*A*) *The Residual Learnings.*—The question of what is retained after a course of study and how long it will be retained is of great educational importance. This question has been studied from a number of angles. Attempts have been made to see what has been retained, how long, and what kinds of materials are retained best. The more encouraging results of recent experiments show that the retention of the application of principles was greater than factual knowledge. This retention was measured over a period of some time.

(*B*) *Testing for Special Learnings.*—More encouraging have been the attempts to test for things other than factual knowledge. The articles show the following test ideas: testing for laboratory technic, for equation mastery, for chemical aptitude, for mastery of chemical principles, and for general achievement.

(*C*) *Types of Tests.*—Interest has centered around the development of new-type (objective) tests, tests combining both new-type and essay examination features, and novel quizzes. The last are in form of the game idea in testing for chemical facts.

(*D*) *Uses of Tests.*—In addition to the uses cited in the introductory paragraph two others may be mentioned: (1) the use of tests to develop a point system for stimulating pupil interest, and (2) the use of tests for instructional purposes. The point of view in the last instance is that we can teach by use of the testing procedure.

(*E*) *Studies of Testing Programs.*—These studies in general relate to the inspection of formal examination program practices. They are concerned with the chemical contests, the mental processes involved in entrance examinations, and analyzing the questions asked in formal examinations.

(*F*) *Test Experimentation and Criticism.*—Articles included in this group include such items as: constructive criticisms of testing procedures, reports of experimental testing programs, and analysis of experimental tests. To paraphrase, this group of reported studies is concerned with evaluating the evaluation procedures.

SUMMARY OF THE PROBLEMS IN THE AREA OF COURSE EVALUATION

(*A*) The Residual Learnings

(1) How long do students retain what they have learned from high-school chemistry?
(2) What is the residue of high-school knowledge that is utilizable in college chemistry?
(3) What type of learnings are best retained?

(*B*) Testing for Special Learnings

(1) What are the measurable outcomes of laboratory instruction?
(2) How can we measure laboratory technic?
(3) How well do the standardized chemical tests measure achievement?
(4) What are the problems involved in the measurement of achievement in high-school chemistry?
(5) How can we test for mastery of chemical principles?
(6) Can we forecast chemical aptitude?
(7) Of what value are tests in writing chemical equations?
(8) What are the best types for equation testing?

(*C*) Types of Tests

(1) Can we combine the essay test with the new-type test?
(2) What has been the success of the objective test in high-school chemistry?
(3) What type of objective tests are most desirable for high-school chemistry?
(4) What has been the history of the development of the new-type tests and what is their present status?
(5) Are novel quizzes good instructional devices?

(*D*) Uses of Tests

(1) Does the point system of grading increase pupil participation?
(2) How can we use pupil errors on tests to improve the instruction?
(3) Is there instructional value in having the pupils correct their own test papers?

(*E*) Studies of Testing Programs

(1) What lessons are to be learned from formal testing programs?
(2) What mental processes are involved in formal test programs?
(3) Do the mental processes involved in formal test programs change from year to year?
(4) Do the questions asked in formal testing programs reflect the type of chemistry being taught?

(*F*) Test Experimentation and Criticism

(1) What are the problems involved in construction and validating examinations?
(2) How can we measure the use of the scientific method?
(3) How can we measure the ability to interpret experimental data?
(4) What do the experimental studies show about the different types of objective questions?
(5) What types of chemical learnings have been recently shown to be best retained?

PROBLEMS THAT ARISE IN THE AREA OF TEACHER PREPARATION

As the concept of education grows and it is no longer identified with one particular aspect of the development of the individual it will be seen that the problems of teacher preparation will tend also to grow in number and in importance.

An examination of twenty-three periodical articles published since 1920 that relate to the problems of teacher preparation shows that they fall in two major groups. They are (1) the problems associated with teacher growth and development, and (2) problems associated with the training of teachers.

GENERAL DISCUSSION OF THE PROBLEMS IN THIS AREA

(*A*) *Problems of Teacher Growth and Development.*—The problems of this division may be briefly described as arising from the following aspects: (1) the development of a professional attitude among teachers, (2) the problems of self-growth, and (3) problems of teacher research.

The development of a professional attitude among high-school chemistry teachers is a subject for a great deal of attention. This problem resolves itself into many aspects all of which cannot be discussed at this time. Self-growth is desired in teachers. Self-growth may be promoted by many schemes. The teacher may use the resources of his or her own immediate surroundings to promote this aspect. Teacher research may be an answer to in-service development.

(*B*) *Problems Associated with Teacher-Training.*—The periodical articles reviewed disclosed an extensive list of problems in this division.

(1) Outlines for courses to train chemistry teachers.
(2) Lists of qualifications for high-school chemistry teachers.
(3) Studies analyzing present teacher-training courses.
(4) Articles citing things ordinarily missed in teacher training.
(5) Trends and tendencies in teacher training.
(6) Discussion of methods training in chemistry.

A casual examination of the discussions in this field will show that the base of teacher training for chemistry is broadening—that the courses not only ask for preparation in subject matter and practice in teaching but also for knowledge in other fields such as education, psychology, and the history of chemistry.

SUMMARY OF THE PROBLEMS IN THE AREA OF TEACHER PREPARATION

(*A*) Problems of Teacher Growth and Development

(1) How can the professional spirit among chemistry teachers be promoted?
(2) What are some self-helps for teacher growth?
(3) What are some outstanding problems in chemical education in which the teacher can do research?
(4) How can the educational and semi-scientific journals be used for research and for self-growth problems?

(*B*) Problems Associated with Teacher Training

(1) What are some good qualifications for a teacher of high-school chemistry?
(2) What qualifications are particularly desirable in the beginning teacher?
(3) How are teachers being trained in college for teaching high-school chemistry?
(4) What are the trends and tendencies in the teaching of chemistry in normal schools and teachers' colleges?
(5) Do we need standards in courses in the teaching of chemistry?
(6) What are some of the unstressed essentials in training teachers for elementary chemistry?
(7) Are these problems to be considered in teacher education; teacher load; salaries; other subjects to be taught; a general survey of working conditions?
(8) How are methods in teaching taught in the educating of prospective high-school chemistry teachers?
(9) What are some good basic references for prospective teachers?
(10) What would be a good outline for a chemistry teacher's training course?

CONCLUSION

During the past few years there has developed a considerable amount of literature dealing with the improvement of the high-school chemistry course. This material has appeared in the issues of various science education periodicals.

It has been hoped that through a study such as this the material so published could be gathered to some extent into a more logical and rational organization; once this arrangement has been perfected that it would better serve the purpose of the high-school chemistry teacher, the students and instructors of science education, and the individual seeking research problems in its use and understanding.

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A REPORT ON THE WORK OF THE NATIONAL COMMITTEE ON SCIENCE TEACHING

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THE National Committee on Science Teaching convened for its fourth meeting Wednesday morning, February 21, 1940 in the Jefferson Hotel, St. Louis. The thirteen members of the General Committee present at this meeting included representatives of the American Association for the Advancement of Science, the American Chemical Society, the American Nature Study Society, the Association of Science Teachers of the Middle States, the Central Association of Science and Mathematics Teachers, and the Department of Science Instruction of the National Education Association. On Thursday and Friday, some fifty consultants met with the general committee, and the whole group divided into several sub-committees to study particular problems.

At this date it is impossible to foresee what the final product of the committee will be, but the point of view of the committee is crystallizing along the following lines. The principal job of the public schools is to prepare *all* of the children for effective living in a democracy. To that end, our educational program must be redirected to meet, directly and specifically, the personal and social needs of all of the children. Science teaching can contribute to this sort of educational program by developing such information, generalizations, skills, attitudes, and appreciations as are necessary for such things as critical thinking, intelligent consumption, conservation mindedness, health, safety consciousness, occupational perspective, recreational interests, a satisfying world picture, and the support of scientific endeavor. The method of science teaching can contribute much to the development of problem-solving ability if teachers can be persuaded to answer pupil questions not with information, but with the counter-question, "How can we find out?"

The educational philosophy of the Committee is well balanced between the extremes of progressive and conservative thought. Some of its members are thinking in terms of the abandonment of traditional subject-matter barriers, so that chemistry, physics, biology, or even science itself will cease to appear in the curriculum as isolated subjects. Others conceive no such drastic changes, but foresee a decided change in emphasis within the subject-matter boundaries. Certainly, the Committee is approaching the problem with an open mind. No vested interests, however strong, appear able to influence the recommendations of the Committee from a selfish point of view.

It is significant that this Committee, having set up effective living in a democracy as the inclusive purpose of American education, has adopted the democratic spirit and democratic procedures in its own deliberations. Policies are shaped and decisions made only after full, free, and open discussion. A determined effort is being made to obtain the coöperation of individual classroom teachers in every part of the country. The report of this Committee is not to be the edict of a grand council. Rather it is to be the distilled judgment of all the science teachers who are willing to participate. While this method of procedure is not the swiftest, nor outwardly the most efficient, it is fundamentally democratic, and has the tremendous advantage of developing a group of classroom teachers who speak and think in common terms. In the long run, it is the individual teachers whose work will determine the success or failure of any program of science instruction.

Any chemistry teachers who are concerned with the future of science education, and who are willing to expend some effort, are strongly urged to join in the work of this Committee. Communications may be addressed either to the general chairman, Dr. Ira Davis, University High School, Madison, Wisconsin, or to the representative of the Division of Chemical Education, Robert L. Ebel, Edison Institute High School, Dearborn, Michigan.

RECENT BOOKS

COLLOID CHEMISTRY. *Robert J. Hartman*, Indiana University. Houghton Mifflin Company, Cambridge, 1939. xxviii + 556 pp. 184 figs. 15.5 × 24 cm. $4.75.

This newcomer to the textbooks on colloid chemistry is one of the best reviews of the subject. It is addressed to graduate students or to advanced undergraduates in chemistry, as well as to students in allied sciences.

The author rightfully states that, "The science of colloid chemistry bridges the gaps between the various physical and biological sciences. It has become an indispensable tool without which it is impossible to explain many scientific phenomena. It is the one field of chemistry which can claim to be the chemistry of everyday life."

The book is refreshing in that it is not simply a rehash of some of the material in a few leading texts filled out by references to papers which happened to have been published in the last year or two. On the contrary, it is a fair cross-section through the material in this field, and the references are distributed over the most important papers throughout the whole development of the subject. The theoretical side is somewhat weak, but this in part reflects confusion among various schools, and it is fully compensated for by the wealth of interesting factual matter. Several chapters might be modernized. For example, the discussion of sedimentation hardly does justice to Svedberg's oil turbine ultracentrifuge or to the established theoretical treatment of Mason and Weaver, Lamm, Faxén, and Archibald.

The book consists of four parts. The first comprises surface chemistry, including adsorption and catalysis. The second is devoted to the preparation and properties of lyophobic systems with separate chapters on aërosols, emulsions, and foams, dialysis and ultrafiltration. The third part deals with lyophilic systems, sols, gels, and jellies. Part IV gives much interesting information with regard to the biocolloids, with further chapters on foods, biocatalysts, colloid factors in growth and movement, and colloids in the blood and nervous system, concluding with one on colloidal medicines. At the end there is a five-page list of reference books.

The book is beautifully illustrated, and the text is particularly clear. It should be widely read. The factual information will appeal to the imagination of many students and lead to their giving the subject much closer attention.

JAMES W. MCBAIN

STANFORD UNIVERSITY
STANFORD UNIVERSITY, CALIFORNIA

CHEMICALS OF COMMERCE. *F. D. Snell* and *C. T. Snell*. D. Van Nostrand Co., Inc., New York City, 1939. viii + 542 pp. 14 × 21.5 cm. $5.00.

This review could be summed up in the words of a research chemist who was asked to read the book and to offer his comment, "Every chemist ought to have it and what's more, I've recommended it be placed on the list to be purchased by those high-school libraries where my opinion has weight."

The authors have undertaken an ambitious project and carried it out successfully. By so doing they have placed their chemical colleagues as well as certain groups of the lay public under a considerable obligation.

The book is a useful tool to practically all branches of the chemical profession as well as to those not chemically trained who need or desire information on what the authors have aptly titled the "Chemicals of Commerce."

The plan of classification by type of compound is particularly helpful, since it makes it easy, when looking up one compound, to quickly obtain information regarding those other compounds likely to be most easily substituted for it or most closely competitive with it.

Specialists in various industrial fields will undoubtedly find it possible to respond helpfully to the authors' request for "criticisms, suggestions, and comments," yet on the whole the wonder is that the authors have found it possible to collect so many facts from so many diverse sources with so infinitesimal a proportion of inaccuracies.

CARL S. MINER

THE MINER LABORATORIES
CHICAGO, ILLINOIS

EXPERIMENTAL FOOD STUDY. *Agnes Fay Morgan*, Ph.D., Professor of Household Science, and *Irene Sanborn Hall*, Ph.D., formerly Instructor in Household Science, University of California. Farrar & Rinehart, Inc., New York City, 1938. xvii + 414 pp. 15 × 23 cm. $3.00.

The book provides a detailed outline for laboratory work, together with discussion material and reference data for a one-year college course (one hundred eighty hours) on the composition and preparation of foodstuffs. "Unlike most manuals in this field, it is written from the experimental point of view and in no way can be considered as a guide for a course in cookery. The approach made is chiefly that of the chemist. . . ." The course is intended to follow one year of general college chemistry and presupposes that other courses will be taken specifically in food analysis, nutrition, and cookery.

The subject matter is divided into three main sections: (1) Food Solutions (one hundred sixty pages), (2) Food Colloids (one hundred fifty-two pages), and (3) Food Emulsions (sixty-seven pages). A large part of the experimental work is qualitative in nature, but many excellent quantitative experiments have been introduced also. Review questions at the end of each chapter include well-selected problems to emphasize the theoretical and quantitative aspects of the work. References to standard books (rarely to journal papers) are given generously for each section of subject matter.

The printing is clear and carefully edited. The text is skillfully worded for elementary teaching and should prove valuable for its intended purpose.

C. G. KING

UNIVERSITY OF PITTSBURGH
PITTSBURGH, PENNSYLVANIA

ERGEBNISSE DER ENZYMFORSCHUNG, Volume 8. Edited by *F. F. Nord* and *R. Weidenhagen*. Akademische Verlagsgesellschaft, Leipzig, 1939. 324 pp. 71 figs. 11 × 19.5 cm. RM. 34.

This volume contains the following reviews: "Purified Viruses and Virus Proteins" by R. W. G. Wyckoff (in English); "Mechanism of Symbiotic Nitrogen Fixation" by P. W. Wilson (in English); "Biological Significance of the pH Optimum of Gastro-Intestinal Enzymes of Vertebrates" by H. J. Vonk (in German); "The Significance of Enzymes in Chemical Diagnosis" by R. Ammon and E. Chytrek (in German); "Enzymatic Analysis of the Antigenic Structure of Pneumococci" by R. J. Dubos (in English); "Low Molecular Transmitters of Biological Oxidation and Reduction and Their Potentials" by F. G. Fischer (in German); "Aldehyde Mutase" by M. Dixon (in English); "Tissue Respiration in Animals" by C. Martins (in German); "Enzymes of Wood-Rotting Fungi" by S. R. Bose (in English); "The Genetics of Biochemistry of Flower Color Variation" by R. Scott (in English).

The present volume of this universal review is at least as interesting and valuable as the preceding seven volumes.

HENRY TAUBER

CHICAGO, ILLINOIS

KAI U. LINDERSTRØM-LANG (1896–)

The chemical section of the Carlsberg Laboratory in Copenhagen has had two internationally famous directors: Kjeldahl (1876–1900) and Sørensen (1900–38). The present incumbent of this important post, K. Linderstrøm-Lang, bids fair to maintain this brilliant record. He was born in Copenhagen on November 29, 1896, and received his first professional training at the Danmark Tekniske Højskole in that city. In 1919 the newly graduated chemical engineer was appointed assistant at the Carlsberg Laboratory, and there entered upon a successful research career. His early papers were in the field of physical chemistry, but he soon began to apply his skill in that domain to biochemical problems. The University of Copenhagen awarded him a Ph.D. in 1939 for his thesis on the fractionation of casein. This work was supervised by Sørensen, whom he succeeded on the latter's retirement in 1938.

Though Linderstrøm-Lang has worked in a variety of fields his main interests have been two: proteins and enzymes. The individuality of proteins, their physical-chemical properties (especially electrochemical), proteolytic enzymes, and methods of analysis (acetone titration) have been the subject of numerous papers. The specificity of peptidases, the reaction between enterokinase and trypsin, histochemical studies of the distribution of enzymes in cells and tissues, and the development of appropriate micro-methods are the main lines of his work on enzymes.

Dr. Linderstrøm-Lang is a corresponding member of the Société Philomathique de Paris, Videnskabernes Selskab, Copenhagen, Akademiet for de tekniske Videnskaber, honorary member of the Harvey Society. He was a Rockefeller Fellow in 1931, and Dunham Lecturer at Harvard in 1939.

(*Contributed by Ralph E. Oesper, University of Cincinnati*)

EDITOR'S OUTLOOK

LESSONS. One of the chief criteria of the success of the educational process is the extent to which it enables the subject to profit from the experience of others. As a nation we are now confronted by a grave test of our ability to learn the lessons purchased by others at horrible cost.

It should now be fairly evident to all of us that a pacific disposition and an inclination to pay strict attention to one's own business are no adequate guaranties of immunity from thuggery.

The writer, for one, has had an overdose of the thesis that there is no calamity as bad as war; that there is no indignity too crushing to suffer, and no tribute too exorbitant to pay, if thereby peace may be maintained. This, like all questions involving differing standards of value, is unprofitable to argue. The final refutation of this thesis is the evidence that one may pay to the uttermost to avoid the supposedly ultimate calamity, and then, weakened and desperate, experience that calamity in the end.

Some New Deal wise-cracker coined the devastating *mot* to the effect that you can't eat personal liberty. Well, what of it? You can't eat a good many other things that make life worth living, either. The standard of values here implied is that of the amoeba. But, again avoiding the discussion of values, we have had ample demonstration that one may sell his birthright for a mess of pottage, and still not get the pottage.

Hitler saved Germany from communism—and gave it Hitlerism. We would do well to see to it that while our leaders are saving us from Hitlerism something analogous doesn't happen to us.

But to return to what most of us cannot at the moment help regarding as the more imminent peril, certain technical lessons are now being laid before us. It would be presumptuous for a layman to attempt a detailed discussion of matters of military technic, but the indications are clear even to a layman that some unprogressive military leaders have now witnessed the success of military operations that they had always maintained to be impossible or impractical. It is to be hoped that our military experts are competent to deal with the detailed problems of tactics and equipment that must be left to them—and there is good reason to think that they are. The lesson to be learned by the general public is that it should not be too readily lulled into a false sense of security by plausible assurances that "they can't do that to us."

SAMUEL GUTHRIE—*An* EARLY AMERICAN CHEMIST

FREDERICK H. GETMAN

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IT IS recorded that Thomas Paine, on learning of the signing of the treaty of peace at the close of the American revolution, exclaimed, "The times that tried men's souls are over." Notwithstanding Paine's confident assertion, history tells us that the termination of armed conflict, in fact, proved to be the prelude to one of the most critical periods in the annals of the nation.

It was into this troubled era that Samuel Guthrie (*1*), the subject of this sketch, was born in the little village of Brimfield, Massachusetts. His father, Dr. Samuel Guthrie, Sr., traced his descent from a prominent family of Scotch Covenanters, one of whom, the Reverend James Guthrie, was tried and hung at Edinburgh, in 1661, for the unorthodox character of his preaching. Continued persecution by the Scottish theocracy finally forced the Guthrie family to emigrate to America. Some of the family settled in Boston, while other members located in various parts of New England. Among the latter was Samuel Guthrie, the grandfather of our hero, who migrated as far west as the Berkshire highlands where he soon became a successful farmer. Upon the declaration of war with England, the elder of Samuel's two sons enlisted in the colonial army and later one of them, Samuel, Jr., settled in Brimfield where, ultimately, he became the respected village physician. Here he married a young woman who, like himself, came of sturdy New England stock and here in 1782 Samuel Guthrie, 3rd, was born. Little is known of Samuel's boyhood beyond the fact that he not only witnessed much of the mob violence incident to Shay's rebellion, but also that he experienced something of the wide-spread distress resulting from the prevailing national financial chaos. Early in his career the lad came to know, contrary to Paine's optimistic prediction, that "the times that tried men's souls" were very far from at an end. Perhaps to this youthful enrolment in the "school of hard knocks" is to be traced much of that courage which Guthrie displayed later in life when called upon to face difficulties.

Upon the completion of such elementary education as was afforded by the Brimfield village school, young Guthrie entered upon the study of medicine under his father's tutelage. Apprenticeship to a practicing physician being the accepted method of acquiring a medical education in the early years of the nineteenth century, Guthrie was more than fortunate in being able to profit by the capable and unremitting instruction of his father. Upon the completion of his studies and after having satisfied such conditions as were imposed upon anyone who might aspire to practice the art of Hippocrates, the young doctor removed to the village of Smyrna in Chenango County, New York, where he commenced his career as a practicing physician. Shortly after settling in Smyrna he married Miss Sibyl Sexton of that village. This marriage, which proved to be a happy partnership, was blessed by the birth of four children, two sons and two daughters. In 1808, Dr. Guthrie, Sr., died, leaving to his son Samuel the modest

FIGURE 1.—HOMESTEAD OF DR. SAMUEL GUTHRIE, SR., BRIMFIELD, MASSACHUSETTS. BIRTHPLACE OF DR. SAMUEL GUTHRIE, JR., IN 1782

bequest of one dollar in cash, one set of catheters, and five volumes of the medical writings of the late Benjamin Rush. At about this time Guthrie appears to have changed his place of residence from Smyrna to the near-by village of Sherburne.

In 1798, Jenner had published the results of his epoch-making discovery concerning vaccination against smallpox. This discovery produced a profound impression upon Guthrie who at once became desirous of the opportunity to demonstrate its value to the residents of the little community in which he then resided. To this end his cousin, Sarah Guthrie, who had previously submitted to vaccination and who at the time was a guest in his Sherburne home, volunteered to act as a nurse to one of Guthrie's patients who had contracted the dread disease. Although both nurse and patient occupied the same room, neither the physician nor his kinswoman became victims of smallpox. The immunity thus conferred by vaccination produced a deep impression upon the farmer-folk round about

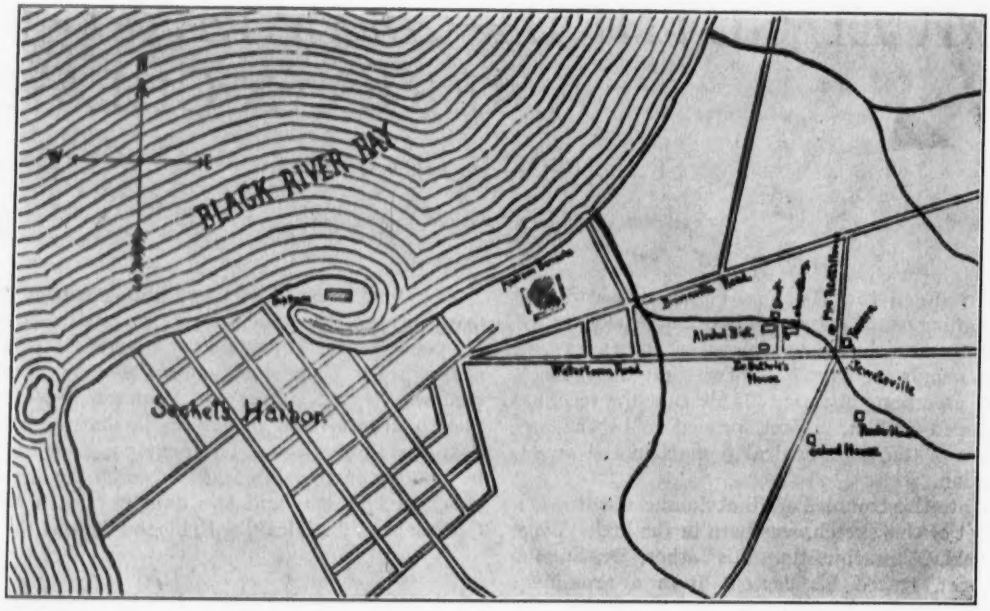

FIGURE 2.—MAP OF SACKET'S HARBOR, NEW YORK, SHOWING DR. GUTHRIE'S RESIDENCE, LABORATORY AND POWDER HOUSE

Sherburne, and Guthrie's reputation as a physician was thereby greatly enhanced. It was also during his residence in Sherburne that he first became interested in the manufacture of gunpowder, an interest which continued unabated throughout the remainder of his life.

During the winter months of 1810 and 1811, Dr. Guthrie went to New York in order to avail himself of certain lectures which at that time were being given at the College of Physicians and Surgeons. Although the occupant of the chair of chemistry was Dr. Samuel Mitchill, a well-known teacher, we have no evidence, notwithstanding his growing interest in that science, that Guthrie attended any of this eminent man's lectures.

Upon the outbreak of the War of 1812 Dr. Guthrie enlisted as an examining surgeon, thus emulating the example of his father, who had served as a surgeon in the colonial army. In the winter of 1815 we find him once again enrolled as a student, this time as a matriculant at the University of Pennsylvania. The chair of chemistry in the medical department was then occupied by Dr. John Redman Coxe. It appears highly probable that Guthrie was a regular attendant at Coxe's lectures on general chemistry and that from them he derived information which proved of inestimable value in much of his subsequent chemical work. It is also not unlikely that Guthrie, at this same time, made the acquaintance of Robert Hare, one of the outstanding chemists of his day. Through the invention of the "hydrostatic blowpipe" and other ingenious devices, Hare's name had already become widely known as one of America's leading men of science, and we may well believe that Guthrie frequently made his way to Hare's laboratory to seek this chemist's advice about the various procedures, concerning which he was then gathering information preparatory to the manufacture of gunpowder and various other chemicals in the factory he hoped soon to establish.

In 1817, Dr. Guthrie removed with his family to Jewettsville, near Sacket's Harbor, Jefferson County, New York. Here he soon erected a small chemical plant for the manufacture of vinegar and for the continuation of his experiments concerned with the manufacture of gunpowder. The sparsely settled village of Jewettsville is located about one mile east of Sacket's Harbor, the site of a United States Army post which had been established in 1812. A small creek which empties into near-by Lake Ontario served not only as a source of of mechanical power, but also as a source of water for the distillery. Within a relatively brief time this chemical plant had acquired considerable importance, not only as a powder factory, where both ordinary and percussion priming powders of a superior quality were manufactured, but also as a chemical manufactory where acetic acid, alcohol, and various other important chemicals were produced. The growing demand for Dr. Guthrie's chemical products eventually resulted in the enlargement of his factory to include a building devoted primarily to the manufacture of alcohol, a laboratory, a shop, and a powder house, the latter being located, for reasons of safety, at some distance from the other buildings. Also, a small dome-shaped kiln erected near the laboratory served for the preparation of the high-grade charcoal required in the manufacture of powder. It is worthy of note that for

some years a large part of the priming powder used in both the United States and Canada was manufactured at this obscure factory in Jewettsville. A one-time visitor to the Guthrie powder house in recalling his visit, writes, "This is dangerous ground, and we must remove our boots, for whoever enters here must either go barefoot or in his stockings and take special care not to move any hard substance which would cause friction or percussion. When the works are in operation everything is necessarily kept damp. Among the machinery here assembled we find the grinding tub with small burr-stones at the bottom where the ingredients, mixed in predetermined proportions, are ground together under water. When the plastic mass has become uniformly mixed, it is then transferred to an ingenious machine known as the 'graining machine' which imparts to the product the desired granular size, usually about that of a mustard seed. The priming powder, or so-called 'percussion pill,' made here is the invention of Dr. Guthrie and this is said to be the only place in the United States where this product is manufactured" (*1*). This brief description gives one a picture of the extent to which the owner's earlier experiments with explosives had developed from the purely laboratory stage to that of successful commercial manufacture.

As might be expected, Guthrie's experiments in this field had involved numerous disappointments as well as the overcoming of many practical difficulties. At a time when chemical apparatus and essential plant equipment were well-nigh unobtainable, his inventive ability and mechanical resourcefulness were frequently severely taxed. Furthermore, the extremely unstable character of the product under manufacture involved the constant risk of injury from explosion. It is not surprising, therefore, that Dr. Guthrie should have experienced numerous accidents during his long career both as an experimenter and as a practical manufacturer of gunpowder. In a letter to his friend, Professor Silliman, under date of September 12, 1831, Guthrie writes, "Nor must you complain against the fulminating character of my letters; for I have lived for many years in the midst of explosions, and even whilst writing this letter, I have been interrupted by the noise of a heavy explosion, followed by a shrill scream of 'fire' from my alcohol distillery. The history of the accidents, effects of explosion, dangers, escapes, and contrivances growing out of my yellow powder business would fill a volume; and with the percussion powder which I now make I have had probably one hundred explosions more or less severe. Thirty pounds of powder is the largest quantity I have had burnt at one time; but the most distressing accident I have encountered, scarcely excepting the burn which I received from yellow powder, arose from putting my hand into a keg containing about four pounds of percussion powder, and cracking a piece of it between my thumb and finger, by which it took fire; roasting my hand and arm, and tearing off most of the skin of my breast, neck and face."

Dr. Guthrie appears to have begun the manufacture of his priming powder in 1826. The exact composition of this material is uncertain, but it apparently was composed of a mixture of charcoal, sulfur, antimony sulfide, and potassium chlorate. Furthermore it is known that shellac varnish was employed to protect the product from moisture and that to this treatment its slow deterioration was attributed. There is a tradition that the French government at one time sent Guthrie a consignment of caps to be primed with his percussion powder, and that, in appreciation of the compliment thus shown him, he furnished them with complete specifications for its manufacture.

When Guthrie had fully perfected his priming powder, he asked the commanding officer of the garrison at Sacket's Harbor for the privilege of demonstrating its efficiency as a detonating agent in firing a cannon (*1*). The commandant having conceded the privilege, Guthrie provided himself with priming powder, along with an ordinary hammer and punch, and proceeded to the fort for the desired demonstration. After the cannon had been successfully fired, however, and before the last reverberations of its discharge had died away, the commanding officer sarcastically remarked, "Soldiers cannot be expected to carry hammers to war." With his faith still unshaken in the efficiency of his priming powder as a detonator, and unwilling to be thwarted by the army officer's sneering criticism, Guthrie repaired to his shop and forthwith proceeded to devise a crude mechanism for eliminating the undesired hammer and punch. To achieve this result, he first removed the flint from the lock of his gun and, thereafter having replaced the flint by a similar shaped piece of steel to one side of which he had attached a small punch, he proceeded to enlarge the original fire-passage at the breech of the gun, and to insert a short threaded plug provided with a central fire-passage communicating with the bottom of the priming-cup. After having ad-

FIGURE 3.—RESIDENCE OF DR. SAMUEL GUTHRIE AT JEWETTSVILLE, NEW YORK. THE LABORATORY, DISTILLERY AND OTHER BUILDINGS ARE NO LONGER STANDING. SCATTERED BITS OF CHARCOAL AND FRAGMENTS OF GLASS MARK THE SITE OF THE FORMER CHEMICAL PLANT

justed the improvised punch so that it would properly impinge upon the cap, Guthrie then loaded the gun, placed a "percussion pill" in the cup and, on releasing the trigger, satisfactorily discharged the weapon, thus completely overcoming the officer's objection to hammer and punch as prohibitive accessories. This hastily improvised device was soon replaced by a greatly improved and much more compact appliance for the discharge of fire arms. To Dr. Guthrie, however, is due the initial invention of the "punch-lock" gun which soon completely superseded the flint-lock gun

FIGURE 4.—SEAL OF JEFFERSON COUNTY HISTORICAL SOCIETY SHOWING GUTHRIE FIRING CANNON WITH HAMMER AND PUNCH

of colonial days and caused the oft-used expression, "flash in the pan," to become reminiscent of a by-gone day. The seal of the Jefferson County Historical Society bears a representation of Guthrie firing a cannon by means of his "percussion pill" and thereby commemorates this historic event.

Although fulminates were not used by Guthrie in the preparation of his priming powder he had, nevertheless, conducted extensive experiments with these materials as is conclusively shown by his correspondence. In a letter to his friend Silliman (*2*), he writes, "I was greatly surprised today, and somewhat chagrined, by reading your observations on fulminic acid, etc., to find myself anticipated in what I was about to claim as a discovery of my own, to wit, that fulminic acid could be transferred to caustic potash and a salt obtained from the union; and that that salt, at less than boiling heat, would be decomposed and yield *ammonia*." He then adds, "After all, I have only verified M. Liebig's discovery of fulminic acid, and devised a detonating compound of tremendous power, which can be prepared with more safety, and at less expense than detonating silver." Later, in 1831, he again wrote to Silliman, "I have delayed sending the chlorate of potash I promised, together with some other things, that I might . . . complete some experiments I have been making on the action of caustic potash on fulminating mercury. . . One hundred grains of mercury, to two measured ounces of acid (nitric acid Sp. Gr. 1.34) and two measured ounces of alcohol, make as good fulminating mercury as I have ever seen. . . . From an expression in your Chemistry, I suspect you doubt the possibility of using fulminating mercury as a means of firing guns loaded with common gun powder. Fulminating mercury used alone for that purpose is useless, because the heat does not continue a sufficient time to ignite the powder; not, that it is not hot enough, for if it be ground with some material that retains heat some little time, it makes one of the most certain primings that can be used. I instituted a great number of experiments to ascertain this fact; and likewise what substance would best answer the purpose, and finally selected oxide of tin. Three parts of fulminating mercury and one part of oxide of tin, ground together with a stiff solution of starch, gave a powder which I have manufactured a great deal, and so far as I know, it has scarcely ever, if at all, missed firing the piece in which it was used." Professor Silliman in a note concerning the foregoing communication writes, "I am impressed with admiration both at his (Guthrie's) skill and intrepidity," a sentiment in which everyone who reviews his work must share!

Residing in an agricultural community where the potato crop was one of the most abundant, it is not surprising to find Guthrie undertaking a series of experiments with a view to converting the starch of the potato into sugar (*2*). Having become convinced from preliminary laboratory experiments that the project was a thoroughly practical undertaking, he succeeded in enlisting the coöperation of his friend Captain E. G. Potter, and together they developed the apparatus necessary for carrying out the process in Guthrie's factory. An ingenious machine was devised by Potter for the maceration of the potatoes to a thin pulp and then effecting the subsequent removal of the starch by means of a current of water and appropriate sieves. For the conversion of the starch into sugar, a strong closed wooden vat capable of sustaining a pressure of ten pounds per square inch and having a capacity of four hundred gallons, was charged with a mixture of two hundred twenty-five gallons of water and four pounds of sulfuric acid together with six hundred pounds of wet starch, this being the amount of the latter to be hydrolyzed at each operation. The circulation of live steam through pipes at the bottom of the converter served to heat the mixture to the desired temperature, while thorough agitation was effected by means of an appropriate arrangement of paddles. A period of five to six hours was required to bring about the hydrolysis of the starch, the completion of the process being ascertained by testing samples of the mixture with iodine. The reaction mixture, after having been neutralized with caustic lime, was then allowed to settle, when the supernatant clear sirup could readily be siphoned off. With this apparatus Guthrie was able

to produce daily about thirty gallons of sirup weighing approximately twelve pounds per gallon. He made repeated attempts to obtain a crystalline product from his sirup but without success despite the fact that—as he wrote to Silliman—"Careful concentration to every possible degree of consistence has been tried." He had noted, however, in the course of his experiments that, when a lead-lined converter was used, a white crystalline product was obtained, but he soon discovered this to be contaminated with lead and hence to be unfit for use. In communicating to Professor Silliman the results obtained in these experiments Guthrie writes, "The sugar may be used for all kinds of domestic purposes. It ferments with great liveliness and spirit, when made into beer, yielding a healthful and delicious beverage, and on distillation, a fine cider-brandy flavored spirit. It would, however, be most useful in making sweetmeats, and may be used upon the table in lieu of honey, for which it is a good substitute. It has already become a favorite with most people who have become acquainted with it. Its taste is that of a delicious sweet and as an article of diet is unquestionably more healthful, and less oppressive to the stomach than any other sweet ever used." Evidently these enthusiastic statements influenced Professor Silliman to give it a trial for he writes, "The use of a bottle (one-fifth of a gallon) in my family, fully supports Mr. Guthrie's statements."

Another chemical problem which engaged the attention of Guthrie was the purification of oil of turpentine. Concerning this problem he wrote (*2*), "Few things that have engaged my attention have cost me so much trouble as divesting spirits, or rather oil of turpentine, of the last particle of its resin." After numerous experiments he finally achieved the desired result by mixing the crude turpentine with an aqueous solution of quick lime and subsequent distillation, but was disappointed to find that the purified oil thus obtained did not prove to be a good solvent for caoutchouc as he had hoped.

Probably the most noteworthy among the many achievements of the subject of this sketch was the discovery of chloroform. While it is not possible to determine the exact date of this discovery, it appears probable that it occurred sometime during the year 1830. Thus Dr. Guthrie's grandson in his personal reminiscence of his grandfather writes, "Shortly after the birth of my brother, April 29, 1831, the family moved from the immediate neighborhood of my grandfather to the village of Sacket's Harbor. Previous to this I was in the laboratory daily and have a distinct recollection of having inhaled the odor of chloroform before that date." From this it seems probable that Guthrie's discovery of chloroform antedates the preparation of this same compound by both Soubeiran in France, who published the results of his experiments in 1831 (*3*), and by Liebig whose experiments were reported in Germany in 1832 (*4*). In an article entitled "New method of preparing a spirituous solution of Chloric Ether" (*2*) which appeared in the *American Journal of Science* in 1832, Guthrie gives the following outline of his method of preparing chloroform: "Into a clean copper still, put 3 lbs. chloride of lime and 2 gals. well-flavored alcohol Sp. Gr. 0.844 and distil. Watch the process, and when the product ceases to come highly sweet and aromatic, remove and cork it up closely in glass vessels. The remainder of the spirit should be distilled off for a new operation. . . . From the above quantity I have obtained about 1 gal. ethereal spirit. By redistilling the product from a great excess of chloride of lime, in a glass retort on a water bath, a greatly concentrated solution will be obtained. This new product is caustic and intensely sweet and aromatic. By distilling the product from carbonate of potash, the product is concentrated and refined. By distilling from caustic potash, the ether is decomposed, and muriate of potash is thrown down while the distilled

FIGURE 5.—GUTHRIE'S PUNCH LOCK RIFLE

product consists of alcohol. During the last six months a great number of persons have drunk the solution of chloric ether in my laboratory, not very freely, but frequently to the point of intoxication: and so far as I have observed, it has appeared to be singularly grateful both to palate and stomach, producing a lively flow of animal spirits, and consequent loquacity; leaving after its operation, little of that depression consequent to the use of ardent spirits. This free use of the article has been permitted, in order to ascertain the effect of it in full doses on a healthy subject; and thus to discover, as far as such trials would do, its probable value as a medicine. From the *invariably* agreeable effects of it on persons in health and the deliciousness of its flavor, it would seem to promise much as a remedy requiring a safe, quick, energetic, and palatable stimulus. For drinking it requires an equal bulk of water."

On comparing the foregoing directions for the preparation of chloroform with the procedures outlined in the papers of Soubeiran and Liebig, it appears that the former treated alcohol with bleaching powder, as did Guthrie, while Liebig first prepared chloral by the action of chlorine on alcohol and then converted the chloral into chloroform with caustic potash, milk of lime, or baryta water. While each man carried on his work in-

dependently and, seemingly, quite unaware of the experiments of his contemporaries, it would appear that priority in the discovery actually belongs to Guthrie (7). In a subsequent communication, Guthrie gives an account of his experiments in the preparation of pure chloroform and includes a summary of its properties. Thus he determined its specific gravity to be 1.486 and

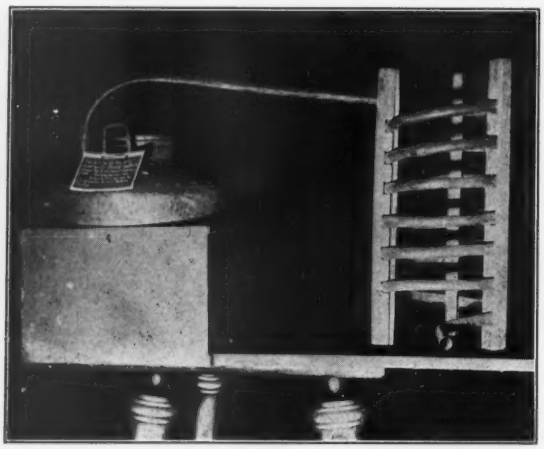

FIGURE 6.—FACSIMILE OF STILL USED BY GUTHRIE IN PREPARATION OF CHLOROFORM IN 1831

its boiling point as 136°F. The values of these respective constants as given in the "International Critical Tables" are Sp. Gr. 1.489 and B. P. 142.2°F., showing that this early preparation compared favorably with modern standards of purity.

While the first use of chloroform as an anesthetic is commonly attributed to Dr. Simpson of Edinburgh, in 1847, it would appear that Guthrie, prior to that date was fully aware of its power to produce insensibility to pain. In a letter to one of his daughters written February 9, 1848, he refers to his interest in chloroform in these words, "I could have made a fortune if I had gone to New York as I was urged last fall, by making 'sweet whisky' which you remember taking when suffocated with charcoal fumes. You see, it is called chloroform, and the papers are beginning to give me the credit of discovering it. I made the first particle that was ever made, and you are the first human being that ever used it in sickness. This is likely to be the greatest discovery in medicine the world ever saw. By breathing it a few seconds the patient falls apparently into a sweet sleep, when breasts, legs and arms may be cut away, painful labors ended and all without pain or injury." In his early attempts to effect complete anesthesia by means of chloroform several of his patients barely escaped with their lives. His first recorded success was in the amputation of a leg of one of the soldiers at Madison Barracks in Sacket's Harbor.

The growth of his chemical business together with his ever-growing interest in the science of chemistry left Dr. Guthrie very little time for the practice of medicine, with the result that he gradually withdrew from the active pursuit of that profession, although he continued to give medical attention to a few favored patients. He found time, however, to supplement his income by collecting and articulating skeletons for medical schools (5). This gruesome avocation earned for him and his negro servant, who shared in the task of collecting and dissecting the required cadavers, a somewhat awesome reputation among many residents of the neighborhood. A story is related of how on one occasion a farmer brought his seven-year-old son to Dr. Guthrie to have him set the lad's broken arm. The doctor gave the boy a few whiffs of chloroform and then, after having set the arm, called to his daughter to "Bring '*John*' downstairs so that I can show which bone is broken." Presently the girl entered the doctor's study carrying in her arms a completely articulated skeleton!

According to his grandson, Dr. Guthrie was a slender man of medium height and with slightly stooping shoulders. His well-formed head covered with an abundance of gray hair combined with remarkably penetrating eyes gave him a truly distinguished appearance. After he had reached middle life he unfortunately became afflicted with tic douloureux: the resulting contraction of the muscles of the left side of face caused not only a partial closure of the left eye but also a distortion of the mouth. Although dignified and somewhat reserved in manner, he is reported to have been very approachable and endowed with a singularly warm heart and generous nature. While extravagance was in the opinion of Dr. Guthrie almost criminal, he considered the expenditure of money for scientific investigation as a most justifiable and worthy investment, meriting the warmest encomiums. A man of very simple tastes, Dr. Guthrie naturally gave little thought to dress although he is said to have maintained a uniformly neat appearance. He made occasional trips to New York and upon his return invariably brought back enthusiastic accounts of recent inventions that he had seen, such as the Morse telegraph and the Daguerreotype. It is believed that Guthrie would have brought home a portrait of himself taken by Daguerre's process had it not been for the disfigurements caused by tic douloureux and numerous explosions in his laboratory. As it is, no portrait of this interesting scientific man is believed to be extant.

The library of Dr. Guthrie, in addition to a goodly collection of medical and scientific books, together with files of a number of scientific periodicals is reported to have contained many books of purely literary character, such as the works of Shakespeare and other standard authors. Among his books none was more read than the holy Bible of which Guthrie was a reverent student. While not believing in the literal interpretation of the scriptures, he was a sincere believer in the basic truths recorded therein and regarded all of the works of Nature as revelations of the Creator's handiwork.

Living as he did in a rural community it is not surprising that, as a farmer, he should have been interested in a wide variety of agricultural pursuits. Thus we

learn that in his well-cultivated fields he was constantly putting to practical test various horticultural suggestions which were appearing in the current issues of the *Boston Cultivator*, and further, that he was among the first to investigate the French sugar beet as a possible source of sugar.

Despite the intense activity of his life he, nevertheless, found time to cultivate the art of music, and he is reported to have been able to stir the emotions of his hearers by the exquisite tones he elicited from a cherished violin.

Both hunting and fishing were sports of which this versatile man was very fond, while an evening of cards with congenial friends afforded him distinct pleasure. A social gathering, however, where aimless conversation was the sole diversion found him silent and ill at ease.

Following the death of his wife, in 1839, Dr. Guthrie went to live with a married daughter who resided a short distance from Sacket's Harbor. While his interest in chemistry remained unabated, his activities in both laboratory and factory, practically ceased with his removal from his home in Jewettsville, and a few years later, in the autumn of 1848, the life of this interesting scientific pioneer came to a close. As we review his career it appears quite probable that had Guthrie been born a century later he would have sought a technical rather than a medical education, but one wonders even so, whether, his achievements would have been more outstanding or whether his contribution to his generation would have been of greater worth. When, early in the 1830's, Silliman wrote, "I presume it was little suspected that such great things were doing in a remote region on the shore of Lake Ontario," he was but emphasizing Guthrie's place among America's scientific pioneers.

As we close this brief sketch of this interesting life we find ourselves in accord with the poet who wrote,

> "Look for us in the darkness at the foot
> Of those high cliffs, under the drifted leaves.
> That's where we hide at last, we pioneers,
> For we are very proud, and must be sought
> Before the world can find us, in our graves."

ACKNOWLEDGMENT

The author desires to record his indebtedness to Mrs. Grace M. Lansing and to Mr. David F. Lane of Watertown, New York, and also to Miss Emma L. Whittemore of Worcester, Massachusetts, for their assistance in securing valuable data for the preparation of the foregoing sketch.

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JOBS *for* GRADUATES *in* CHEMISTRY

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IN A recent canvass of chemical executives, mostly industrial, the following question was asked.

"What strikes you as the one principal shortcoming of the college graduates who enter your employ?"

To the surprise of some persons, the replies yielded no complaint that the young bachelor of science did not know how to weigh, filter, or distil, or that he was short of chemical information. On the contrary, the laboratory directors seemed to have forgotten that they were hiring men qualified primarily in chemical science. I quote Chief Chemist A.

"The boys do not know how to write good English or to organize their material. Recently I asked one of our newest college graduates to run a series of tests on rubber samples, and to report results to me. The tests were acceptably done, but the report is not intelligible. We are quite willing to teach this young man rubber technology; but we think that the problem of clear and coherent writing of notebooks and reports belongs to the educational institution from which he came!"

After deciding that this testimony was more pertinent than pleasing, we quizzed Chief Chemist B, a petroleum expert, carefully avoiding comment on the first answer.

"If a young chemist is going to progress in this company, he will soon find himself in an office. Can he dictate anything intelligible to a stenographer?

"Here on my desk lies a telegram from the head office in San Francisco. I must answer this at once in a few words. Words cost money over the wire. I must get my point over without offending the chief executive at the other end of the line, but without the possibility of misunderstanding."

Chemist C continued the argument with similar views, figuratively addressing the young man directly.

"There is something stubborn in your makeup which I know well from experience. You take your problems in mathematical chemistry very seriously. You admit their importance. But English composition—not literary production but plain effective presentation of scientific fact and logic—does not impress you until at last you bump into some utterly practical executive in industry who tells you what you should have realized in school days."

Chemical Engineer D puts in a word for oral English. He describes a scene where the chief chemist, quizzed by manager, engineer, and division superintendent, interrupts an office conference to summon a young employe from the laboratory where the latter has been working out the details of an experiment under discussion. Some young chemists, thus "put on the spot," waste time with superfluous apologies about the sorry appearance of their laboratory aprons. They stumble over the simple problem of describing their work, repeating the tiresome platitude "you know," when as a matter of fact the auditors don't know. Another employe, on the contrary, who has paid some attention to simple public speaking, goes directly to the point and presents his facts clearly. After such an employe is excused from the conference the first comment from the manager is not on the chemical problem, but rather on the personal merits of the man who has just departed.

Those who do not continue for higher degrees should realize that the bachelor of science in chemistry, launched into industry, will be primarily occupied in production, sales, or purchase, not research. There are of course low-paid routine jobs connected with research, but these do not offer promise of advancement in that field. Mr. E, production manager for a multi-million-dollar chemical industry, testifies,

"We don't hire routine employees for technical service. We always have more of them than we need, left over from tryouts in various departments. We bring in only those who we think have a chance to become managers, superintendents, chief chemists. We know full well that we will often miss our guess. To be sure, when we do miss our guess, we do not pronounce the employee as a failure, even though he doesn't have the 'spark.' " Mr. E then described the young man who does have the "spark."

"We put a half-dozen new boys in a laboratory, tell them what they are to do, and walk out. Next day we return. We find Bill Jones running the place and *the other five liking it.* Bill's the man we are looking for!"

Although each executive has a slightly different story, upon one point they are unanimous. They are all looking for the *alert* fellow. Alertness, however, does not mean vivacity, talkativeness, or snappy style of speech. It does not necessarily mean A grades in college, though to be sure the chances are higher in the "A" bracket. Alertness probably does not start *de novo* within the being of a young man after graduation, but apparently it may in his sophomore or junior year. It has nothing to do with high-strung nerves, phlegmatic temperament, fatness, leanness, or nationality. Alertness is never twice characterized by just the same activities. Mr. F, college professor, throws light on the question by the negative method of describing a non-alert student.

He is primarily a course-taker and unit-accumulator.

He is always talking about methods of getting grades instead of an education.

The professor he had last year cannot remember who he is when the department chairman makes a personal inquiry.

He never tries any specialties or unusual methods.

He feebly complains that the chemistry department doesn't tell him where to find the answers to the questions at the end of the chapter. He alleges that they always did this for him in high school.

When the professor schedules a small research problem in the advanced laboratory course, he expects the University (including the storekeeper) to tell him everything that is to be done. If the problem does not solve itself as smoothly as the preparation of nitrobenzene, he looks sadly and reprovingly at the professor.

He never "browses" in the chemical library, but uses that institution only for required assignments and for comfortable quarters in which to work problems in physical chemistry.

He never tries glassblowing, assuming that he would make a mess of it.

He never builds a potentiometer, homemade after the manner of a radio set, or a private automatic water bath, or fixes up conveniences for himself in quantitative analysis.

He is surprised at the result of throwing a damaged liter bottle into an empty waste crock, and suggests that we get better crocks.

He never seeks an assistant's job for any other purpose than dire financial need.

He never shows symptoms of proprietorship, or shows any positive interest in the University's property.

He never discovers an obsolete piece of apparatus which he can adapt to his needs.

He never does anything which was not specifically assigned by the instructor or laboratory manager.

He never puts in overtime except to suit his own sweet convenience; *e. g.*, to finish a distillation in Experiment 15, or to complete a qualitative "unknown" analysis while his sleeves are rolled up.

He knows nothing of the research problems under way in the laboratory, or who is working on them, or who is directing them.

He has no "inside knowledge" of anything. He never observed the difference between sodium and potassium dichromates; that wasn't given in any of his courses. The problem of storing sal soda, calcium chloride, or sodium sulfite he has never heard of.

He doesn't know any chemist or laboratory worker excepting his instructors and fellow students. When the professor during the lecture writes the names "Midgley" and "Whitmore" on the blackboard, he leaves them out of his notes; what's the use? They won't help in the final examination.

When this poor wretch finally looks for a job, the personnel officer sends him over to see Mr. G, chemical engineer in the firm.

"You think you want an oil job, do you? Have you applied to any other company?"

"Yes," admits the young man with an unnecessary guilty look.

"Where?"

"Standard Oil Company."

"Whom did you meet there?" counters Mr. G.

"Oh, I don't exactly know; the man in the office!"

At this juncture the applicant receives the standard formula of soothing words of dismissal, and shortly finds himself out in the street thinking Mr. G is a rather nice fellow after all. This engineer continues with advice to young applicants, summarized as follows.

Don't begin by making vague impersonal inquiries at the central offices about employment. Find out who the chief chemist, superintendent, or manager is *by name*. If none of these gentlemen can do anything for you, get them to suggest others by name in other industries. You will certainly not hurt your chances by telling the next executive, "Mr. X suggested that I see you."

Show interest in a quiet but kindly way in the activities of the prospective employer and his associates. You are of course inexperienced, and dare not bluff about your capabilities; but show firm confidence that you can do the kind of work wanted at that plant. Study from the standpoint of your own special personality the neat distinction of being smart but not smart Aleck.

Be cheerful. Job-hunting is not helped by solemn and sorrowful looks. An employer is not one whit attracted by a look of desperation on the face of a twenty-three year old graduate. If he's that way at twenty-three, what will he be like at thirty-three?

Let your prospective employer know if you have ever had successful experience in managing men. For example, did you once run your father's print shop for two months during a serious parental illness?

Don't be deceived by an offer of temporary employment, declining it on the ground that you want a steady job. One chief chemist regularly uses this device to sift the good ones from the poor ones. With the latter he saves face by merely notifying them that the temporary job is done.

Be prepared to answer this sudden question from your would-be employer—"Why do you think you can be of service to this company?" Remember that the employer, officially speaking, is not at all interested in your need for income. His business is to make profits for the company, and to that end he may see value in you.

If you are given a blank form to fill out, be sure to sign your name to it, and give all necessary street and telephone numbers. This childish advice is really needed, according to the local employment committee of the American Chemical Society. If now you do get a job elsewhere, have the courtesy to notify the other fellow, with thanks, that his attention is no longer needed. This might pay some day.

THE ATTITUDE OF THE NEW EMPLOYE

Assuming now that the young graduate has at last landed a job, the chemist-executives continue their advice.

Remember that it is not your admirable personality which will win you favor half so much as a *lack of annoying habits*. Read the illuminating editorial by Howe[1] pointing out the manifold ways in which an employe can irritate his fellows and his chief, working eight hours daily in their company.

Work accurately. Even at the risk of being branded as a slow performer for the time, get the results right before you report. Your boss will never give you real responsibility until he knows that your work doesn't need checking by him. But watch: in your desire for accuracy, don't make a foolish struggle for one-tenth-per cent. precision when two per cent. meets the industrial requirement and saves half the time.

Don't expect the chief chemist to tell you all the details of your little problem. Later when he has to refer an inquiring superintendent to you for those details, take courage. You are progressing.

Don't tell the chief that you "don't like" gravimetric analysis, prefer synthesis, and so forth. If you are ever to be a higher-up yourself, you must know at first hand how the plant carries out many operations, and you are not going to become popular by emphasizing dislikes which are trivial anyway.

Don't miss a chance to manage employes. It may be only a dirty job bossing three ignorant laborers, but seize it, and give it your most serious attention; that is, not only the mechanics of the job, but its psychology. Assuming that you have learned the art of working with your fellow employe, you sooner or later face two more problems: (*a*) how to get along with the boss, and (*b*) how to get along with the subordinate. Mr. G continues with a concrete illustration of each.

(*a*) You have had the good sense to join the American Chemical Society and attend its local meetings. You do not wait feebly for people to shake your hand. You initiate cheerful dinner conversation yourself. As a result of all this you discover an interesting new friend

[1] HOWE, *Ind. Eng. Chem.*, **28**, 627 (1936).

who is chemist for a concern manufacturing cutting oils.

Some weeks later you happen to catch a telephone call at the laboratory. A client, observing that your firm is an "oil" company, wants to know about cutting oils, which you do not handle. You know just what to tell him. But wait a minute. You ask the client to hold the wire, and you consult your chief chemist. The chief has no such fresh information, and you quickly provide him. Perhaps he will send you back to the phone; or he may relay the information himself, giving the weight of the company's official recommendation, whatever that is worth. Briefly, do not try to take the credit for minor services, even if the chief is selfish. It may be that he fears you, an alert newcomer with modern training; not for today, or tomorrow, but for the uncertain future. A little expression of loyalty on your part will not hurt your standing in that laboratory.

(*b*) After you have put in many months as analyst, wielder of the pipe wrench, control chemist, still operator, and so forth, your superiors have decided to promote you. It happens that your new job sends you back to the old still house where for several months you personally served as operator. Your old job is now held by an uneducated practical operator, a man of forty who has a wife and two children. You have the task of getting this man to help you effect some small improvements in distillation for which your education and short experience seem to fit you. But you are only twenty-six years of age.

It happens that your new subordinate has been detained unduly by some chore in the adjoining shop. In the meantime you notice that the pressure gage reads three hundred pounds. It should be two hundred fifty. Stop and think a moment. Is this an emergency, with the safety of the Company's property hanging in the balance? If so, turn the proper valve; you know the equipment and the remedy. But if no such emergency really exists, *don't touch that valve!*

Find your man and question him tactfully and quietly. Results will be had immediately. The subject is not mentioned again—to the operator, the superintendent, or the manager, unless real trouble should arise. By this technic you have avoided making for yourself an enemy, but you haven't yet made a friend.

Your operator is secretly afraid of you, an upstart whose practical skill he discounts, but whose scientific training he cannot match. He is no "chicken," and he has learned some of the devious ways of the world. He can do, or fail to do, a lot of intangible things which will brand *you*, not him, as an inefficient research engineer. In brief, he considers you a threat to his job, since you are not there as a superintendent but merely as a special deputy. You have on your hands chemistry, physics, and psychology, and the greatest of these may be psychology.

You now really start to work. Admitting fairly your shortage of practical experience, do not hesitate to ask the operator's advice every time the question is reasonable. Perhaps the operator becomes a bit independent, however, and proceeds to carry out the program in his practical way. Now is your turn to be smart, if you are reasonably lucky. If he can succeed with his hunch methods, this merely demonstrates that somebody blundered in sending you out there. The job was too easy. More likely, however, he won't "get away with it." Let him hang himself with his own ropes, not long enough to harm the Company, or to delay the game too much, but long enough to make him appreciate help.

At this juncture—or it may be several junctures—you enter the picture with a simple matter-of-fact offer of help. There is no sarcasm, no "I-told-you-so" or airing of scientific language. You simply get him out of his troubles. Perhaps the superintendent learns of the trouble, but you claim no individual credit. "We fixed it up."

When the operator finally learns that despite your few years you have no desire to lord it over him or anybody else; that you recognize his place with the Company and are sincerely anxious to preserve his position as well as yours; in short that you are a "good guy," then your chances in chemical industry are bright.

SOME CATALYTIC REACTIONS[1]

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WHEN the velocity of a reaction expressed as cc. of gas absorbed in a given time is plotted as a function of time, a curve passing through a maximum is obtained (Figures 2 and 3). "The time necessary for the reaction to reach its maximum velocity" is called the induction period (*1*). It is obvious that the general effect of a catalyst is to decrease the length of the induction period in a given reaction. The term, "autocatalytic" suggests that the catalytic effect is developed as the reaction proceeds. Several cata-

[1] Presented before the Physical Science Section of the Pennsylvania Academy of Science, State College, Pa., April 7, 1939.

lytic reactions are to be considered in some of which "autocatalysis" is apparently involved.

The first reaction to be considered is the so-called "drying" of linseed oil (*2*). In this investigation, known weights of linseed oil, with and without drier, were placed successively on strips of cloth from the same sample. These strips, of the same size, were stretched upon wire frames and placed in a closed system which supplied oxygen at atmospheric pressure

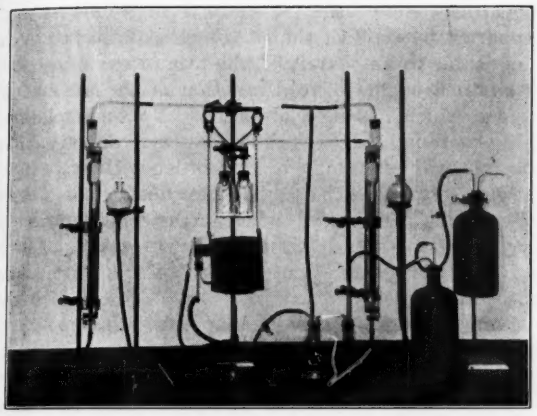


FIGURE 1.—APPARATUS FOR MEASURING THE RATE OF ABSORPTION OF OXYGEN BY LINSEED OIL

(Figure 1). The reaction vessel containing the cloth was immersed in boiling water so that a temperature of approximately 100°C. was maintained. By working at 100°C. it was possible to carry through a given experiment within one hundred minutes. Figure 2 shows the curves for data obtained with raw linseed oil alone and with driers. Driers used were linoleates of cobalt, manganese, and lead containing 0.1 per cent. of metal calculated on the weight of the oil used in each case. It will be observed that the maxima were much higher and the induction period was much shorter in the experiments in which driers were used.

In an investigation of the rate of drying of linseed oil paint, Nicholson and Holley (*3*) obtained results closely analogous to those of Currier and Kagarise, although, a different technic was employed. The method was essentially a gravimetric one, in which the sample of paint, of known weight, was spread upon a glass plate in a film of known thickness.

The glass plate was placed upon the balance pan of a chainomatic balance which was housed in a specially constructed chamber through which pure dry oxygen was passed at a known rate. Special devices for manipulating the chain, beam, and pan from the outside made it possible to weigh the samples *in situ*. Figure 3 shows the velocity-time curves for two samples containing respectively cobalt resinate and cobalt naphthenate with the same concentration (0.038 per cent.) of cobalt in each.

Other curves shown by Nicholson and Holley indicate that variation in the quantity of metal (cobalt) used in the drier caused a variation in the length of the

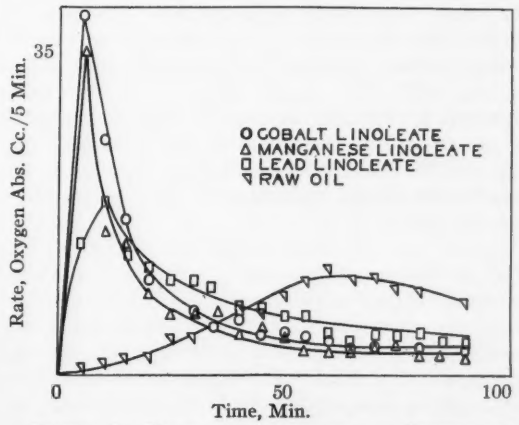
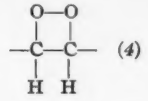


FIGURE 2.—RATES OF ABSORPTION OF OXYGEN BY LINSEED OIL USING LINOLEATES OF COBALT, MANGANESE, AND LEAD WITH 0.1 PER CENT. CONCENTRATION OF METAL IN EACH SAMPLE

induction period, a fact which was also observed by Currier and Kagarise (*2*).

Although the chemical mechanism of drier action and the changes that take place in the drying of oils is not fully understood, two fairly well-defined processes are known to take place, *viz.*, (1) absorption of oxygen with the formation of a peroxide type of structure,



(*4*)

and (2) polymerization resulting in the formation of polydimensional molecules of high molecular weight,

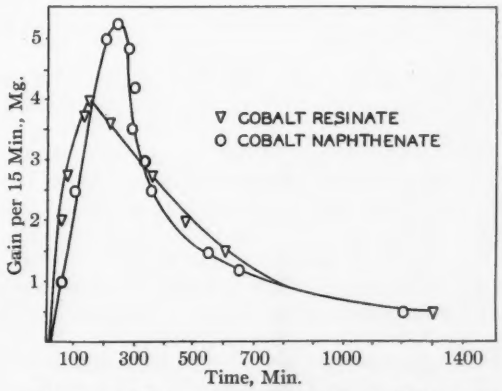


FIGURE 3.—RATES OF ABSORPTION OF OXYGEN BY LINSEED OIL PAINT CONTAINING COBALT RESINATE AND COBALT NAPHTHENATE WITH 0.0389 PER CENT. COBALT BY WEIGHT

of the resin type and insoluble. It has been postulated also that the energy necessary to initiate polymerization is supplied by the oxidation process.

Another factor not hitherto considered in the problem of the mechanism of the drying of oils is the interface effect. The writer suggests that "autocatalytic" effects in the case of the drying oils, may be developed at the interface between the liquid oil phase and the resulting solid resin phase composed of the oxidized polymerized product. It may be that the oxygen or the oil or both are activated at this interface. As a basis for this view, attention is now directed to some experiments on the reduction of nickelous oxide by hydrogen (*5*).

Benton and Emmett ascribe an "autocatalytic" effect, in the case of the reduction of nickelous oxide, to the nickel–nickel oxide interface which is developed during the reaction. This reaction appears to be analogous to the reduction of copper oxide by hydrogen, investigated by Pease and Taylor (*6*), and others. During the course of this reaction, copper nuclei were observed to form rapidly and thus set up an increasing copper–copper oxide interface. It was observed that when reduced copper was placed in contact with the copper oxide before reduction was started, the induction period was of shorter duration. The supposition is made by these investigators that "the oxygen atoms of the oxide are rendered more active by contact with free metal." Benton and Emmett refer also to earlier work by Langmuir (*7*), in which it is shown that in the decomposition of calcium carbonate by heat, an interface is formed between the two heterogeneous phases, calcium carbonate and calcium oxide, which accelerates the rate of decomposition. It is of interest to note here that a somewhat analogous case was investigated by G. N. Lewis (*8*) ("Zersetzung von Silberoxyd durch Autokatalyse"), in which he states that the "autocatalyst" is metallic silver.

The oxidation of cyclohexene is of interest because other factors are apparently involved in the reaction. Stevens (*9*) concludes from his study of this reaction that the induction period is not due to autocatalysis but is caused by inhibitors (impurities[2]) which retard the attainment of the maximum rate. This view is supported by the fact that if the increase in rate with time is due to autocatalysis, the rate of oxidation at a given time ought to be a function of the amount of oxygen which has been absorbed. No such relationship was found. It was shown, on the contrary, that the rate was essentially of zero order with respect to oxygen—a fact which suggests the effect of some rate-determining factor independent of the concentration of oxygen. This rate-determining factor was considered to be the rate of activation of the hydrocarbon molecules at the walls of the vessel.

From this brief survey, it is apparent that reactions of the so-called autocatalytic type are extremely complicated. In these reactions, as in many other catalytic reactions, a complete explanation of the mechanism is difficult to attain because of the transitory intermediate steps in the gross process.

[2] The most exhaustive purification failed to eliminate the induction period entirely.

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MEETING OF THE EXECUTIVE COMMITTEE, DIVISION OF CHEMICAL EDUCATION

At a meeting of the Executive Committee held April 9, 1940 in Cincinnati, the following action was taken.

(1) A motion carried that we discharge the Committee on Chemical Education of Non-Collegiate Type, with thanks and that we appropriate funds necessary for one hundred reprints of its report and "Trade Analysis."

(2) Mr. McGill, Chairman, reported that two men had been added to his Committee on High School Chemistry: T. A. Nelson of Decatur, Illinois High School; and R. D. Reed of New Jersey State Teachers College, Montclair, New Jersey.

(3) Dr. Charles Parsons, Secretary of the American Chemical Society, had asked the Executive Committee to name a Committee to work with Committees from some other organizations on "Improvement and Organization of the Teaching of Physics and Exact Sciences in High Schools and Grade Schools." A motion carried that our present Committee on High-School Chemistry shall constitute such a Committee.

(4) The Secretary of the Board of Publication reported that the Board had elected Dr. N. W. Rakestraw as Editor of the JOURNAL OF CHEMICAL EDUCATION for the term August 1, 1940 to September 1, 1942.

PAUL H. FALL, *Secretary*

ZIRCON

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Zircon is chiefly zirconium silicate ($ZrSiO_4$) although most specimens contain traces of many other elements. It has a wide geographical distribution. Its chief use is as a gem stone, its clearness, fire and adamantine luster making it a close rival to the diamond.

✦ ✦ ✦ ✦ ✦ ✦

INTRODUCTION

IT IS difficult to understand why a mineral having all the excellent gem stone properties of zircon should have been so slow in winning its present popular favor. Perhaps it is because there has been some question as to the genuineness of certain colored specimens, or it may be because there have been so many unanswered questions about the composition and properties of this "gem of mystery."

The name zircon is generally said to come from the Arabic words zirk (a jewel) or zarqun (vermillion). Others trace it to the Persian word zargun (gold colored) (*1*). In Sanskrit it is known as Rahuratna, signifying the stone of the nodes of the moon. The red varieties are called Hyacinth for the youth Hyakinthos, beloved of Apollo. A yellow species is known as Jacinth while "jargoon" includes many colors. The Ceylonese call the colorless variety "Matura Diamond." Recently the name "Starlite" has become very popular for the blue and green shades (*2*). Early Sanskrit books mention a ring called the Nava-ratna, set with the nine most precious stones of the time, one of which was zircon.

This mineral was one of the twelve stones in the breast plate of the Hebrew High Priest as well as forming one of the twelve foundations of the New Jerusalem. It was placed with other jewels in the Dar-as-Salem, the Arabian garden of peace.

Zircon has also played its part in the history of chemistry. In 1789 Klaproth analyzed a specimen of zircon from Ceylon and reported that it contained seventy per cent. of a new earth which he called zirconderde. From this "earth" Berzelius later obtained the element zirconium.

SOURCES

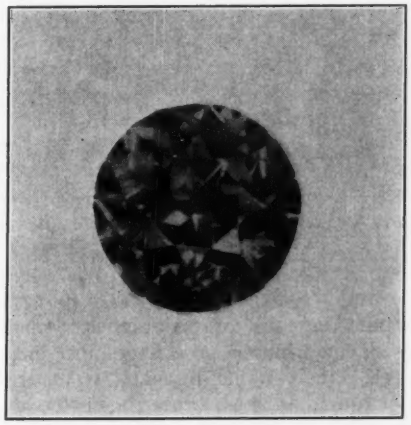
The reported deposits of zircon are of such a wide geographical distribution that it is very likely that new finds may be reported at any time.

Known to the miners as "Dutch Boort" it is found in the Kimberly diamond mines of South Africa (*3*). The grease used in the "jiggers" to separate the diamonds from other minerals also collects the zircons, and the two must later be separated by hand-picking methods (*4*).

Other occurrences of note are Expially, France (*5*), the Ilmen and Ural Mountains in Russia (*6*), Mugee, New South Wales, Australia (*7*), Canada (*8*), India (*9*), Upper Burma (*10*), Madagascar (*11*), Ceylon (*12*), (*13*), (*14*), and Siam (*15*). Colorado, New York, New Jersey, Maine, North Carolina, South Carolina and Idaho have also reported deposits (*2*).

Zircon is said to be the only gem stone of natural occurrence in France (*16*).

For many years Ceylon was always listed with the chief producers but at present, "There is no mining for zircons as such in Ceylon. They are found but only incidentally in mining for other stones" (*17*).



Courtesy of American Museum of Natural History, New York City

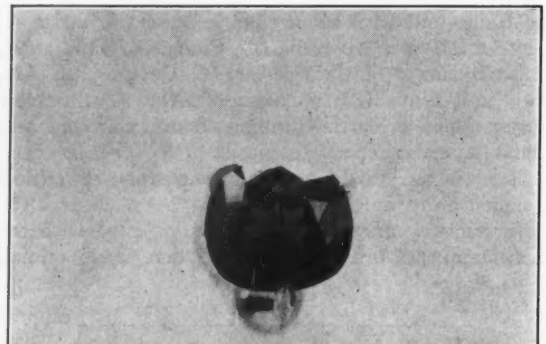
BLUE ZIRCON FROM SIAM

Venable (*7*) says that Mugee, New South Wales, is the "source of the finest zircon gems." The Canadian reports state that many crystals of enormous size and remarkable beauty have been found there. Some of the individual crystals weigh about fifteen pounds and are more than four inches in diameter.

In India and Burma the excavated mud containing the zircons is dumped on iron grates to remove the larger rocks present. The material going through the grates is dumped into water-fed trommels. The finest material from here goes into washing pans and a series of jiggs. The final product representing only about one-fourth of one per cent. of the original mud, goes

on sorting tables. The sorters are required to wear large gauze-fronted boxes over their heads to prevent them from secreting any stones in their mouths. In addition they are carefully watched by a foreman.

Siam is now one of the chief countries supplying the gem stone trade. "The zircons are mined in Chantaboon and along the western border of Siam. The mining is done by individuals rather than companies, and principally by Chinese. The rough stones are delivered in Bangkok for cutting or shipment to foreign



Courtesy of American Museum of Natural History, New York City

HYACINTH ZIRCON FROM CEYLON

countries, and there are quite a number of small shops, generally under Chinese proprietorships, engaged in cutting the gems. While Bangkok is an important market for rough zircons because the cutters are available here, the greater portion of the rough zircons delivered here are said to come from Indo-China; some stones mined in Burma are also delivered here for cutting or marketing. The greater portion of the zircons shipped from Siam go to the United States, with smaller quantities being sent to Europe and India. Shipments to the invoice value of about one hundred forty thousand dollars a year are being sent to the United States (*18*)."

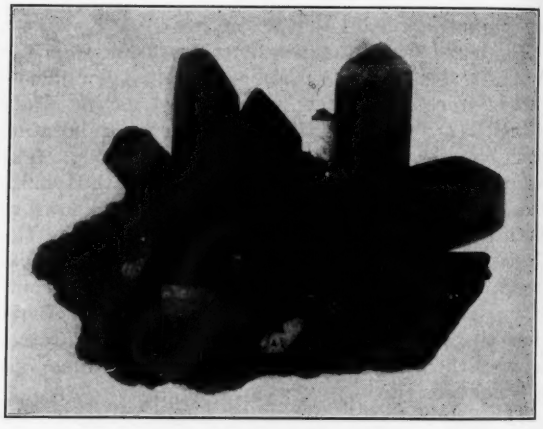
COMPOSITION AND PROPERTIES

Zircon is chiefly the silicate of zirconium ($ZrSiO_4$) although it is seldom found in the pure state. Small amounts of many metals have been reported in various analyses (*19*). A specimen from Monte Somma Vesuvius, for example, was found to contain Hf, Ti, Ce, La, Nd, Pr, Sm, Yt, Dy, Ho, and Er (*20*).

Due to the simplicity of the structure of zirconium silicate it has been possible to determine the situation of the oxygen atoms around the silicon atoms with high accuracy. The zirconium and silicon atoms are fixed in position by the symmetry requirements of the tetragonal lattice. The oxygen atoms build a regular tetrahedron around the silicon atoms with an oxygen-silicon distance of 1.64 Å. and an oxygen-oxygen distance of 2.64 Å. (*21*).

When fused, zircon was found to dissociate into ZrO_2 and a high SiO_2 glass (*22*).

Various samples of zircon have shown such differences in their physical properties that it has been proposed that they should be divided into three classes (*4*). The first class favors green, sky-blue, and golden-yellow colors. It never shows any trace of crystal faces, has nearly single refraction and the refractive index varies from 1.790 to 1.840, the specific gravity from 4.00 to 4.14 and the hardness about 7.5. A second type is characterized by honey-yellow, light green, blue, and red shades. It shows crystalline faces with tetragonal symmetry. Its double refraction runs from 1.923 to 1.932 while the extraordinary is from 1.967 to 1.993. The specific gravity varies from 4.67 to 4.71. It is slightly harder than 7.5. Neither of these types is changed, except in color, by heating.



Courtesy of United States National Museum

ZIRCON CRYSTALS

Between these two classes is a third which is mostly yellowish green, cloudy blue or green. Heat has a striking effect on it. It contracts in size so that the specific gravity increases as much as three units in the first decimal place and corresponding increases are found in the refractive index and double refraction. It is usually characterized by a banded or zonal structure.

Color is also a basis for classification and valuation.

The hyacinth variety is generally designated as having an aurora red, but Whitlock (*16*) believes the color of the juice of a ripe plum is a closer approximation.

The blue and colorless types are the most popular in the gem trade. There has been much difference of

opinion as to whether these varieties occur as such in nature or are the result of some sort of treatment. The fact that there was such questioning is probably one cause of the delayed popularity of zircon. Any treated stone, even if it is essentially genuine, is considered by some people to be a deception. Whatever may be the case as to natural color the fact remains that colors can be and are changed by proper treatment. And many of those who contend they have seen the natural blue stones feel that the artificially blued ones surpass them in color and fire. The simplest method of decolorizing is by firing. The usual practice is to heat the stone between 700 and 1500°C. very slowly and cool at the same rate (*2*). Kunz (*23*) states the brown variety can be changed to blue by heating in a crucible out of contact with fire but exposed to the fumes from a mixture of potassium ferrocyanide and cobalt nitrate for six to eight hours. After cutting, an additional five- to twenty-minute treatment is used. Other methods than these may be in use as many of those engaged in this work will not reveal the processes used.

SUBSTITUTES

Synthetic spinel is the gem stone most commonly employed as a substitute for zircon. An easy means of distinguishing these two minerals is given by Wade (*24*). "Hold the synthetic stone in bright sunlight and allow the colored reflections to fall on an opaque white card. The card should, of course, be held in the direction of the sun but so as not to shade the stone. The true zircon gives double images, pairs of colored spots that move as pairs when the stone is slowly moved. The synthetic substitute gives single colored spots that move about independently of each other as the stone is moved."

Due to its clearness, fire, and adamantine luster a properly cut and polished zircon is a very close rival to the diamond, and occasionally they are palmed off as diamonds. However determinations of specific gravity and hardness give easy means of distinguishing between the two.

USES

Chemically purified zircon and electrically fused zircon oxide have been used for semi-permanent foundry molds, refractory bricks, cements, ladle nozzles, crucibles, and porous refractory diaphragms with good results (*25*).

Zircon crystals have found considerable use as watch jewels and supporting edges for analytical balances.

This mineral is becoming increasingly popular as a gem stone which is its chief use. The colorless stones are generally cut as brilliants and the colored ones with brilliant cut fronts and step-cut backs. Rose and table forms are also used. Wade (*24*) has made a very careful study of the angles which the lapidary should use to give a zircon brilliant its greatest effectiveness.

Of the one hundred sixty-nine rings of the British Museum set with gems cut from a single stone forty-five are zircons.

For ages this gem stone has been worn as a talisman. Cardanus, writing in the sixteenty century said he was accustomed to carry a zircon with him in order to induce sleep which "it did seem somewhat to confer, but not much." It was also believed to render the wearer pleasant and agreeable, be conducive to obtaining money, cheer the heart, strengthen the mind, preserve the traveler from all perils, bring bountiful harvests to the farmer, procure honor and wisdom, act as a charm against plague, thunderbolts, and evil spirits, sharpen the appetite, help digestion, and take away sin. What more could one ask?

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PYROTECHNIC SNAKES

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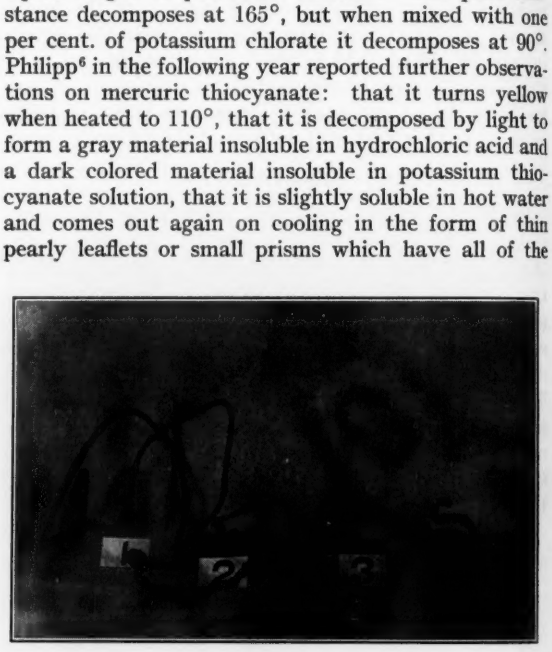
THE sale of the mercuric thiocyanate Pharaoh's Serpents,[1] with which many of us amused ourselves as children, is now forbidden by law in several of the states, for the vapors from these toys are poisonous, and, more serious, children have been known to eat them with fatal consequences. Many of the youngsters nowadays will have to wait until their high-school or freshman chemistry course before they can see a demonstration of the extraordinary property of the mercury salt. They can, however, purchase non-mercury Black Snakes, made entirely from organic materials, the composition of which is as much of a mystery to the generality of chemists as it is to the children who play with them.

Wöhler,[2] while still a medical student at Heidelberg in 1821, first reported the remarkable property of mercurous thiocyanate—which he prepared by precipitating mercurous nitrate with potassium thiocyanate—that it swells up when it is heated "winding out from itself at the same time worm-like processes, to many times its former bulk, of a very light material of the color of graphite, with the evolution of carbon disulfide, nitrogen, and mercury. On further heating the same material remains along with mercuric sulfide. The swollen mass obtained by gentle heating, when ignited with copper oxide, gives a gas consisting of carbon dioxide and nitrogen in the proportion in which they would be formed by the combustion of cyanogen" —and hence consists of paracyanogen.

Mercuric thiocyanate gives better snakes than the mercurous compound. When a heap or pellet of either of these substances is set on fire, it burns with an inconspicuous blue flame, producing sulfur dioxide and mercury vapor. The resulting pale brown or pale gray snake, if broken, is found to be much darker in the interior, and evidently consists of paracyanogen and mercuric sulfide, the mercury having been burned and vaporized from the outer layer.

Mercuric thiocyanate was first prepared by Berzelius[3] in 1821 by the action of thiocyanic acid on mercuric oxide. Claus[4] reported that mercurous thiocyanate is precipitated only in dilute solutions, that concentrated solutions of potassium thiocyanate and mercurous nitrate give a black precipitate which consists of metallic mercury mixed with mercuric thiocyanate. Otto Hermes[5] appears to have been the first to report the preparation of pure mercuric thiocyanate by precipitation, although he suggests in his paper of 1866 that it was already in use in commercial *Pharaoschlangen* which, he says were made up with two per cent. of potassium chlorate. He stated that mercuric thiocyanate explodes powerfully when rubbed with an equal weight of potassium chlorate. The pure substance decomposes at 165°, but when mixed with one per cent. of potassium chlorate it decomposes at 90°. Philipp[6] in the following year reported further observations on mercuric thiocyanate: that it turns yellow when heated to 110°, that it is decomposed by light to form a gray material insoluble in hydrochloric acid and a dark colored material insoluble in potassium thiocyanate solution, that it is slightly soluble in hot water and comes out again on cooling in the form of thin pearly leaflets or small prisms which have all of the properties of the precipitated material, and that it is soluble in cold hydrochloric acid and in potassium thiocyanate, potassium chloride, ammonium chloride, and mercuric nitrate solutions.



BLACK SNAKES. NO. 1 FROM NAPHTHOL PITCH. NO. 2 FROM β-NAPHTHOL BY THE USE OF FUMING NITRIC ACID (1.50). NO. 3 FROM β-NAPHTHOL BY THE USE OF C.P. NITRIC ACID (1.42). NEAR THE NUMERAL 3 ARE TWO PELLETS LIKE THOSE FROM WHICH THE SNAKES WERE PRODUCED

Since mercuric thiocyanate is soluble in an excess of the reagents from which it is prepared, it is best procured by adding a potassium or sodium thiocyanate solution slowly and with stirring to a solution of mercuric nitrate to which a small amount of ferric chloride solution has been added. The appearance of the red

[1] Compare "An historical account of Pharaoh's serpents," by H. Irving in *Sci. Progress*, **30**, 62–6 (1935). I am indebted to Professor Ernest H. Huntress for calling my attention to this article.

[2] WÖHLER, *Gilbert's Ann. d. Phys. u. phys. Chem.*, **9**, 272 (1821). This is the same as Volume **96** of *Gilbert's Ann. d. Phys.*

[3] BERZELIUS, *Schweigger's J. f. Chem. u. Phys.*, **31**, 42 (1821). This is the same as Volume **1** of *Jahrbuch d. Chem. u. Phys.*

[4] CLAUS, *J. prak. Chem.*, **15**, 401 (1838).

[5] HERMES, *J. prak. Chem.*, **97**, 477 (1866). The statement of Hermes, without experimental support, that the voluminous, snake-like residue consists of melam is evidently in error.

[6] PHILIPP, *Poggendorff's Ann. d. Phys. u. Chem.*, [5] **11**, 86 (1867).

color of ferric thiocyanate, if it is not dispelled by stirring, indicates that enough of the thiocyanate solution has been added. The white precipitate is collected, washed, dried, and powdered. The powder is moistened sparingly with a weak aqueous solution of gum arabic, "to which may be added a pinch of saltpeter,"[7] and is made into small cylindrical or conical pellets which are known as Pharaoh's Serpents' Eggs. If too much of the gum arabic water is used, the material assumes the consistency of heavy clay and is difficult to handle. On a plant scale, little truncated cones of the material are made by pressing the composition into holes, larger at one end than at the other, bored through a sheet of metal or a slab of hard wood, and then pressing the pellets out by means of a second board or sheet of metal studded with pegs which match the smaller end of the holes in the first piece. In the laboratory, pellets are made conveniently by means of two pieces of glass tubing, fire-polished at the ends; the wider piece about ten cm. long is supplied with a plug made from a cork stopper, which plug is to be moistened in order to move more freely when the instrument is in use, while the second tube about twelve cm. long fits within the other and is used as a plunger for pushing the cork plug. The composition is pushed into the tube against the cork plug; then, while the end of the tube is held against a flat surface, it is compressed to a compact pellet which is finally ejected by pushing the plunger.

"Snakes in the Grass," "Volcano Snakes," and so forth, depend upon the use of ammonium dichromate. If this material in the form of powder is made into a conical heap, and a flame applied to the top of it, a visible but not violent "combustion" proceeds through the mass which "boils up" to form a large volume of green material (Cr_2O_3) resembling tea leaves. In practice, more flame is desired than ammonium dichromate alone will give. Weingart[8] recommends a mixture of two parts of ammonium dichromate with one of potassium nitrate and one of dextrine. Tin foil cones are made from circles of tin foil shaped on a former, and are introduced by means of the former into conical cavities in a block of wood; they are then about half filled with the powdered mixture, a Pharaoh's Serpent's Egg is pressed in, and the edges of the tin foil are turned down upon it to form the base of the cone. A shallow wooden box filled with the ammonium dichromate mixture in which five or six Serpent's Eggs are buried makes an amusing toy, and may be fired by means of a piece of blackmatch.[9]

Black non-mercury snakes were apparently first made commercially in Germany, and are at present fairly common in this country around the Fourth of July, in the form of "Barrel Snakes," "Hat Snakes" (black pellets affixed to black discs of pasteboard to form what look like miniature broad-brimmed black hats) "Colored Fire Snakes," and so forth. The first indication of the possibility of such snakes appears to be a report by Vorbringer[10] in 1867 that he had procured a brownish black product, which burned to form black snakes, by the nitration of a certain black, resinous, acidic material from coal tar, but he did not describe his raw material in such manner as to identify it and to make it available to others. The method of making black snakes was kept secret, and does not appear to have been described in accessible print until Weingart[11] published an account of it in 1937. Ten parts of powdered "naphtha pitch" is mixed intimately with two parts of linseed oil, seven parts of the strongest fuming nitric acid is added a little at a time, and the mixture is allowed to cool for an hour. The product is washed thoroughly with water, dried, powdered, mixed with three and one-half parts of powdered picric acid, and made into pellets with gum-arabic water.

Several questions at once suggest themselves. What is "naphtha pitch?" Will some more common material serve as well? What is the technic of nitrating twelve parts of material, largely solid, with seven parts of nitric acid? Is the linseed oil necessary, and what purpose does it serve?

Correspondence with various American manufacturers failed to discover anything which is known as "naphtha pitch." A sample of "naphthol pitch," a by-product of the manufacture of β-naphthol, was kindly supplied by the Calco Chemical Division of the American Cyanamid Company. This was a dark-brown, shiny, brittle material, having a conchoidal fracture and easily reduced to a cocoa-colored powder. In response to an inquiry as to how he carried out the nitration, Mr. Weingart replied that he "rubbed up the pitch with linseed oil in a Wedgewood mortar and added the acid, a little at a time, so as to avoid excessive heating"—and kindly sent a sample of the "naphtha pech" of German origin which he used in his own work.[12] This material was a dark brown, almost black, granular powder. Both the "naphthol pitch" and the "naphtha pech" reacted vigorously with nitric acid. When mixed with linseed oil and *nitrated by kneading* (if we may give a name to the technic), each yielded a friable product which burned to form a snake while a Bunsen flame was played upon it, but which did not maintain its own combustion. Powdered with picric acid and made into pellets as described, the

[7] WEINGART, "Dictionary and manual of fireworks," Bruce Humphries, Inc., Boston, **1937**, p. 152. This book contains many good formulas, and is recommended strongly to the chemist who wishes to try his hand at the making of fireworks.

[8] WEINGART, *loc. cit.*, p. 154.

[9] The black "fuse" made by passing a few pieces of cotton string, twisted together, through a slurry of finely pulverized black gunpowder and allowing to dry while stretched on a frame.

[10] VORBRINGER, *J. prakt. Chem.*, **102**, 187–8 (1867). This is an editorial note, signed "W" (Gustav Werther) based upon a letter from Vorbringer, describing experiments carried out in the laboratory of the *Mineralöl- und Paraffin-Fabrik des Herrn Dr. Hubner in Rehmsdorf bei Zeitz.*

[11] Weingart, *loc. cit.*, pp. 152–3.

[12] Mr. Weingart also stated that he had obtained satisfactory results by using, instead of "naphtha pech," the material procured by melting together sixty parts of Syrian asphalt and forty of roofing pitch. Worked up in the regular way, this "yielded fairly good snakes which were improved by rubbing the finished product up with a little stearine before forming into pellets."

product from each yielded excellent snakes, smooth-skinned and glossy with a luster like that of coke, elastic, and of spongy texture within. The pellets burned with a luminous, sooty flame; a pellet one cm. long and eight mm. in diameter gave a snake about 1.3 meters in length.

A satisfactory procedure was found to be as follows. Ten grams of powdered naphthol pitch is mixed intimately with two grams of linseed oil, and the material is chilled in a 100-cc. pyrex beaker surrounded by cracked ice. Seven cc. (not seven grams) of fuming nitric acid (density 1.50) is added in small portions, one drop at a time at first, and the material is stirred over, kneaded, and kept thoroughly mixed at all times by means of a porcelain spatula. The addition of each drop of acid, especially at the beginning of the process, causes an abundance of red fumes, considerable heating, and some spattering. It is recommended that goggles and rubber gloves be worn, and that the operation be carried out in an efficient hood. The heat of the reaction causes the material to assume a plastic condition, and the addition of the acid ought not to be so slow that the material becomes hard. After all of the acid has been added, the dark brown dough-like mass becomes friable on cooling. It is broken up under water with the spatula, rinsed, and allowed to stand in water overnight, then washed thoroughly on the filter and allowed to dry at laboratory temperature. The product is ground up with three and one-half grams of picric acid, made into a moist meal with gum-arabic water, and pelleted. It yields about twenty pellets one cm. long and eight mm. in diameter. These should be allowed to dry for four or five days at room temperature before they are used.

An experiment was carried out in accordance with these directions except that the linseed oil was omitted. The powdered mixture of nitrated naphthol pitch and picric acid, when made into pellets with gum-arabic water and dried, burned with a sooty flame, but did not give snakes. Another portion of the mixture was made into a sticky meal with linseed oil and compressed into pellets. The pellets, when lighted, started to give snakes but did not maintain their combustion. After they had stood in the laboratory for two months, during which time the linseed oil had oxidized and the pellets hardened, they gave excellent snakes. The conclusion is indicated that oxidized linseed oil is necessary for the formation of the snakes, and that this component of the mixture is conveniently assured by mixing linseed oil with the naphthol pitch before nitration.

Since naphthol pitch is not easily procurable, some other material was sought—some common laboratory chemical from which a chemist may easily prepare black snakes for his own amusement or for the edification of students. Anthracene was tried with the thought that the rather violent nitration is accompanied by oxidation, which perhaps may result in the linking together of a number of aromatic nuclei, to form a material predisposed toward the production of a carbonaceous residue—but the product melted in the flame, gave no snakes, and did not maintain its combustion. Technical β-naphthol was found to be satisfactory. When the procedure described above was tried with ten grams of technical β-naphthol instead of ten grams of naphthol pitch, seven cc. of fuming nitric acid (density 1.50), and so forth, the pellets gave good snakes, thicker than those from the naphthol pitch but not so long, not so shiny, blacker, and covered with wart-like protuberances or having a segmented appearance. A similar experiment with β-naphthol and seven cc. of ordinary C.P. nitric acid (density 1.42) gave better snakes, somewhat longer and smoother than those from the experiment in which fuming nitric acid was used, but still not as good as those from naphthol pitch. The snakes from β-naphthol, however, are perfectly good, and will probably be satisfactory if none from naphthol pitch are available for comparison.

The NATURE *and* ORGANIZATION *of* SCIENTIFIC KNOWLEDGE

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FREQUENT references to "a scientifically adjusted tariff" or "a scientific income-tax schedule" on the part of political speakers reflect the faith of the common man in "science" to give him what he wants. The word "science" popularly signifies physics, chemistry, geology, and biology and their various subdivisions, and it is the success of these sciences in meeting the material wants of men that is responsible for the popular faith in the power of science to cope with our political and economic problems. Most of the "science courses" in our schools and colleges have as their announced object the training of future citizens in scientific methods and habits of thought. This is particularly true of non-professional general courses.

Unfortunately the usual textbooks used in such courses give only a very hazy notion of the pattern of scientific

knowledge so that their transfer-value to problems of everyday life is all too slight. In what follows an attempt will be made to pick out the underlying pattern which is common to the several branches of physical and biological science. It may be that restricting the name "science" to these branches of knowledge unjustly excludes such things as history and political economy, but to begin by arguing this point would serve no useful purpose and would probably lead to a definition so all-embracing as to be quite useless. The proper course in an enquiry of this sort is to examine a number of authentic samples and then to see how far the doubtful cases conform to the established type. It is better and easier to enlarge where necessary a too-narrow definition than to attempt the limitation of an indefinitely broad one.

Natural science deals with phenomena, *a phenomenon being some object or event (or combination of them) which we perceive with our senses.*

For scientific purposes it is essential that a phenomenon be perceptible and if possible actually perceived by more than one observer. If one man, standing in the midst of a crowd, should alone declare that the sun is green, the phenomenon would be regarded as physiological or perhaps psychological—certainly not as astronomical. If, however, he should return from a desert island and report a green sun, the statement would be placed on record for what it might be worth. If subsequently other Robinson Crusoes made similar reports, the attention of science would be drawn either to the peculiar atmosphere of the island or to a possible correlation between solitude and visual hallucinations. Hunger belongs to a class of phenomena which are perceived subjectively and which from their nature are not perceptible to more than one observer. Physiologists meet this situation by picking out what is common to the independent accounts of different observers.

"For the same two normal human beings the organs of sense are also machines of the same type and thus within limits only capable of conveying the same sense impressions to the brain. Herein consists the similarity of the Universe for all normal human beings." (Karl Pearson, "The Grammar of Science.")

When a phenomenon is carefully examined and the observations are recorded, these records are called data. Data may be obtained in either of two ways: by bare observations and by experimental observations. *A bare observation is one made by an observer who has no control over the influences acting on the phenomenon observed.* Selection of a particularly favourable time or place for making the observation does not constitute control. Neither does the simple act of measurement unless the conditions of measurement (temperature for instance) are controlled. *An experimental observation is one made by an observer who does exercise some control over the influences acting on his material.*

To be of value, either kind of observation must be made carefully and impartially, and it must be recorded.

Accurate description requires a clear understanding of the exact meaning of each word used, for thoughts must eventually be cast into words. The coining of new terms and the growth of a scientific terminology ("scientific jargon") are the natural outcome of this necessity for clarity and precision in scientific writing.

Care, impartiality, and honesty in the gathering of data are the very corner-stone of science, for without reliable data no sound superstructure can be erected. Realization of this has enabled science to draw its greatest strength from its distrust of its own data! Experiments and observations must be checked, rechecked, and cross-checked. One must ever be on the watch for error and misunderstanding. Darwin is reported to have said that Nature will tell you a direct lie if she can!

Sometimes it is said that science deals with facts. Whether this is correct depends on the meaning attached to the word "fact." To the average person, "Fact" implies "Truth." Very little experience with either the making of experiments or the construction of sentences is enough to show that every measurement has a residuum of error and every sentence is but an approximation to the thought of the writer. It is therefore better to say that science deals with *data*—data which are almost certainly not true but which are the best obtainable approximation to it. The truth can only be hinted at.

When data have been collected, sorted, arranged, and classified (and, if need be, checked), then certain regularities may appear. That is, it may be possible to correlate one set of observations with another, or the appearance of one kind of behaviour with the incidence of one set of influences. An obvious example is the well-known correlation of the positions of the sun and moon with the height of the tide. On the basis of such a correlation a generalization or law may be formulated. *A generalization or "Law of Nature" is merely a statement that under given circumstances certain phenomena can generally or always be observed.* Many, if not all, scientific laws are statistical, that is, they hold accurately for large assemblages of atoms or animals, but are no more than statements of probability when applied to individuals or small groups. Recognition of this is most important in biology and in physics when we seek to formulate or apply laws relating to the behaviour of individual organisms or particles. The phenomena of chemistry usually involve such large numbers of atoms or molecules that the statistical aspect of chemical laws can generally be overlooked.

The purpose of a generalization is to enable observations to be transferred from one case to another. The transfer is naturally attended by some uncertainty at first, and it is an essential part of the scientific method to subject every generalization to the widest possible test of experiment and observation. Such testing almost always leads to the discovery of definite limitations on the applicability of the generalization. Few laws are always, absolutely, and universally exact; the simple gas laws of Boyle and Charles are valid only at relatively high temperatures and low pressures.

When, as knowledge increases, it is found necessary thus to modify or restrict apparently well-established laws, this means simply that their limitations have been more clearly recognized, and our confidence in what remains is proportionately increased.

While it is true that generalizations are formulated on the basis of data, very often generalizations are suspected by the observer before he has the data on which to establish them. This is perfectly legitimate, and the observer is no less competent or scientific, so long as his preconceptions do not affect the integrity of his data. *A preconception used as a guide in making observations or experiments is called a working hypothesis.* Working hypotheses are among the most useful tools of science when properly used.

When data have been accumulated, and a number of generalizations formulated, an attempt may be made to relate them by means of a theory. That is, certain assumptions are made and it is shown that these assumptions enable one set of generalizations to be deduced from another apparently unrelated set of generalizations. For example, the Daltonian atomic theory by making certain assumptions about atoms enabled the laws of definite, of multiple, and of reciprocal proportions to be deduced from the laws of the conservation of mass and immutability of elements.

It is sometimes supposed that a theory explains a set of generalizations. In the sense that a theory makes coherent an otherwise incoherent body of knowledge, this is true. It is popularly supposed, for example, that the atomic theory affords an explanation of the basic facts of chemistry. Actually, so long as the law of mass-conservation remains unexplained, the basic facts of chemistry remain "unexplained"—although made much more intelligible by the atomic theory which gives a concise description of them. A theory may be likened to a map which provides a bird's-eye view of a complicated terrain and enables the relation of one part to another to be discerned.

It is the existence of classification and generalization, and above all, of theory that enables science to be described as an *organized* body of knowledge.

We are now in a position to frame a clear definition of the terms theory and hypothesis, and to draw a rather simple distinction between them. *An hypothesis is a more or less plausible assumption used in constructing a theory.* (This is, of course, distinct from the conception of a working hypothesis already defined.) *A theory is a whole body of knowledge, data, generalizations, and assumptions, knit together by a train of logical reasoning.* The majority of textbooks fail to draw a clear distinction between the words theory and hypothesis, and leave only an impression that hypotheses are ill-found theories and theories no more than hypotheses not quite so ill-found. The proposed definitions are more clear-cut and afford a better idea of the organization of scientific knowledge.

It is essential that the number of assumptions used in constructing a theory be kept at a minimum.

When we hear that some well-known theory has been modified or abandoned or overthrown, it means that the discovery of new generalizations or the amendment of old ones has required some change in the current set of assumptions and attendant reasoning in order that the new knowledge may be fitted to the old.

Logic, which is an integral part of all theories, is of two kinds, qualitative and quantitative. "Common logic" is qualitative logic, mathematics is quantitative logic. This reveals the true relation of mathematics to science, a relation that is often misunderstood. Quantitative, mathematical logic is needed as soon as the technic of observation has advanced to a point where quantitative data and quantitative generalizations are possible. To say that a study is not scientific until this stage is reached is to miss the whole point of the scientific method. It is logical thinking of whatever sort which is essential to science, and attempts to reduce qualitative generalizations to mathematical form in the hope of being thereby more scientific, are merely pathetic—or funny.

"Mathematics has no symbols for confused ideas." *Logic consists of certain rules for reasoning from premises to conclusions which normal and civilized men have agreed to adopt.* "The same type of physical organ receives the same sense impressions and forms the same 'constructs.' Two normal perceptive faculties construct practically the same Universe. Were this not true, the results of thinking in one mind would have no validity for a second mind. The universal validity of science depends on the similarity of the perceptive and reasoning faculties in normal, civilized men." (Karl Pearson.)

It is necessary to draw a clear and sharp distinction between hypotheses on the one hand and simplifying assumptions and restrictions on the other.

A simplifying assumption is a simplification of an hypothesis made for reasons of logical expediency. For example, in the kinetic theory of gases, we may assume (as an hypothesis) that the molecules occupy a finite volume. For purposes of mathematical computation, we may suppose that the molecules are spheres of assigned radius. Attributing a spherical form to gas molecules is a simplifying assumption which may or may not be justified. If it fails to lead to verifiable deductions, it is the simplifying assumption rather than the hypothesis which is discredited.

A restriction is an assumption concerning the conditions under which a system is to be examined or a generalization applied. In working out the theory of a chemical reaction, we may postulate that the substances concerned occupy a constant volume. The data used to verify the predictions of the theory must conform to this restriction or the test is not a fair one.

Reviewing what has been said, a few points require special emphasis.

Science takes for granted the existence of an enduring external world with things in it. Science readily admits that these things (phenomena) are known to us only through our senses, and does not worry much about

"reality." It is content if the impressions received are consistent (that is, reproducible and uncontradictory) and coherent (that is, capable of being related one to another). Science therefore excludes from its scope all knowledge obtained from other than sensory impressions (from intuition or revelation, for example) unless such knowledge is capable of being tested in the ordinary way—when the intuition becomes a working hypothesis.

Recorded observations constitute the data from which generalizations are drawn, concerning which assumptions are made and around which theories are constructed. The important thing about science is its impartial and critical attitude to its own data which demands the checking of observations by different observers. The individual can only be scientific when he is one of a group.

While a science may be born out of purely observational data, history shows that the fullest and most fruitful development has been attained only when both observational and experimental data are available.

Theories serve a threefold purpose. In constructing them the aim is always to link together generalizations that are as far apart as possible. The more far-reaching a theory is the more useful it is. In this way theories weld science into a compact whole.

Again, a good theory in addition to linking generalizations that are already known will usually suggest hitherto unsuspected generalizations. The search for data to prove or disprove these predictions serves both to enlarge the general body of knowledge and to test the usefulness of assumptions embodied in the theory. The great difference between a scientific theory and a pseudo-scientific one is this: that a scientific theory stands or falls by the correctness of its predictions, while a pseudo-scientific theory is upheld because its logic is sound or its assumptions plausible.

Finally, by providing links between generalizations, theories often enable us to bridge the gap between a field where experiment is possible and one where only observational data are available. This is beautifully illustrated by modern astrophysics. Perhaps some day economics will advance to this stage.

Let us now see what practical value there is in the foregoing analysis.

First, it emphasizes the nature of scientific data and the attitude of science toward its data.

Second, it is a reminder that generalizations are founded in data and derived from data. They are tested by gathering more data. They can only be attacked by adducing conflicting data. The question of what "ought" to be does not enter, it is purely and simply a matter of what "is."

Third, it shows that a theory combines the three elements, generalizations, hypotheses, and logic. Therefore, any theory can be examined as to the soundness of these three ingredients, *but the criteria of their soundness are quite different.* A generalization is justified or discredited by data. Logic consists of agreed rules for reasoning. Hypotheses are justified by, first (and least important) their success in correlating generalizations, and second (and critically important) their success in leading to verifiable predictions. A theory that only lets us be wise after the event is useless. It is not necessary that a theory should predict everything—but what predictions a theory does make must be correct. This criterion of utility is the only criterion of an acceptable hypothesis. Plausibility is not important. (Compare relativity and wave mechanics.) Bound up with the criterion of utility is the question of simplicity. That theory is the most useful which is the simplest, which means capable of linking the most generalizations with the help of the fewest assumptions.

The criterion of an hypothesis is its usefulness. The criterion of a simplifying assumption is its fairness and convenience. The criterion of a restriction is its applicability in a particular case.

In conclusion, we may add a word concerning definitions. *A definition is a form of words stating the meaning of a word.* There are two sorts of words to be defined: the words used in describing phenomena are of one kind; some of the words used in framing hypotheses are of the other.

A word used in describing phenomena must be defined in such a way as to enable any person possessed of the necessary skill and facilities to recognize the thing defined. Every technical word used in a generalization must be defined in this way. The word "element" is sometimes defined as indicating a substance composed of one kind of atom only. As a definition this is worthless—unless it be taken as defining the word "atom!" The word element should rather be defined somewhat as follows (at any rate for chemical purposes). An element is a pure substance (previously defined) which cannot be separated into parts having different chemical properties (previously defined) by the use of ordinary physical and chemical methods.

The second kind of word is that used to designate something hypothetical. Atoms, molecules, valence bonds, electrons, and so forth, are whatever we choose to say they are, they have whatever properties it may be useful to assign to them. Definitions of words of this kind may be altered almost at will. Definitions of words of the other kind can only be altered if it becomes evident that the previous definition was incomplete or ambiguous.

PITTSBURGH SUMMER ANNOUNCEMENTS

Professor Wojciech Swietoslawski, formerly Head of the Physico-Chemical Institute in the University of Warsaw and the present Chairman of the Committee on Physico-Chemical Standards of the International Union of Chemistry, will offer lectures in the Department of Chemistry, University of Pittsburgh, on calorimetry and ebulliometry, from July 2nd to July 30th.

LIQUID AMMONIA RESEARCH *in* 1939—*A* REVIEW[1]

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THE publications which have appeared in this field of investigation during the past year cover an unusually wide variety of unrelated subjects. An attempt has been made to classify the various studies in a manner which will render certain topics more readily available to the reader whose interests are specific. In doing this, however, numerous difficulties were encountered and it is recognized that the classification of certain items covered in this review is somewhat arbitrary.

I. PHYSICOCHEMICAL STUDIES

Ritchey and Hunt (*7*) have determined the vapor pressure difference, at 25°C., between pure liquid ammonia and liquid ammonia solutions of ammonium chloride ranging in molality from 0.0051 to 0.900. The densities of the solutions over the range of concentrations studied were also determined. These data have been used as the basis for calculation of activity coefficients for ammonium chloride in liquid ammonia. This information, together with the earlier results of Yost and co-workers (*8*, *9*), has been used to calculate certain standard electrode potentials. As applied to the activity coefficients of ammonium chloride in liquid ammonia, the Debye-Hückel theory had been found to hold only at very low concentrations. Kikuti (*10*) has described studies of the specific gravities of liquid ammonia solutions of ammonium chloride, sodium chloride, and mixtures of these two salts. The measurements for the individual salts were carried out over the temperature range, −30° to 70°C. and from zero concentration to saturation. Plank and Hunt (*11*) have determined the viscosity of liquid ammonia. The values reported, together with the corresponding values for the density of liquid ammonia, are given in Table 1.

TABLE 1

Temperature °C.	*Density* g./cc.	*Viscosity* (av., g./cm. sec.)
5°	0.63197	0.001618
15°	0.61821	0.001457
25°	0.60427	0.001350

A comparison of these values with the data from an earlier investigation indicates that the temperature coefficient of viscosity for ammonia is much smaller than that for any other known liquid. Values for the viscosity at (20°C.) of liquid ammonia-water mixtures ranging from 0 to 80 per cent. H_2O have been reported (*11a*). A maximum viscosity at 71–2 per cent. H_2O corresponds to $NH_3 \cdot xH_2O$, where $x = 2$ or 3.

The influence of ionic size on solubility and solvation in the systems (KI, KCl, KBr, KNO_3)–NH_3 and [$Mg(NO_3)_2$, $Ca(NO_3)_2$, $Sr(NO_3)_2$, $Ba(NO_3)_2$]–NH_3 has been studied over the temperature range −50° to 50°C. (*12*). It was found that the solubility of the potassium halides in liquid ammonia increases with increasing anionic radius. The solubility of zinc nitrate (*13*) has been found to increase from 20.11 g./100 g. NH_3 at −77° to 33.62 g. at −39°, to *decrease* to 29.01 g. at 0°, and then increase to 85.40 g. at 125°. Zinc nitrate was found to form ammonates containing 10(−75° to −55°), 8(−55° to 0°),6 (0° to 58°), and 4 (above 58°)moles of NH_3/mole of salt. The solubility of cadmium nitrate was found to decrease from 29.5 g./100 g. NH_3 at −76° to 0.28 g. at 37°. Sigetomi (*14*) has studied the binary system $NaNH_2$–NH_3 and the ternary system $NaNH_2$–NaCl–NH_3 over the temperature range −20° to 20°C. Values for the solubility of sodium amide in liquid ammonia are given in Table 2. The solubility of sodium amide and of sodium chloride was found to increase rapidly upon addition of sodium chloride or sodium amide, respectively. Amagasa and co-workers (*15*) have studied the system sucrose–liquid ammonia and have described a method for the determination of the vapor pressures of unsaturated solutions of sucrose in liquid ammonia. Certain empirical equations relating concentration, vapor pressure and temperature, and vapor pressure have been proposed for this particular system.

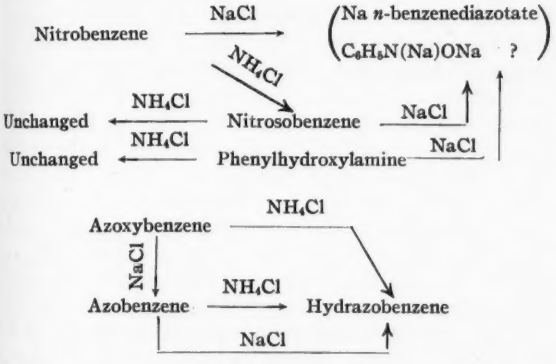
It has been observed that glycogen dissolved in liquid ammonia does not diffuse through a cellulose membrane permeable to sucrose (*16*).

Measurements of the overvoltage of hydrogen on certain metals in liquid ammonia have been made by Pleskov (*17*). The overvoltage of hydrogen on nickel

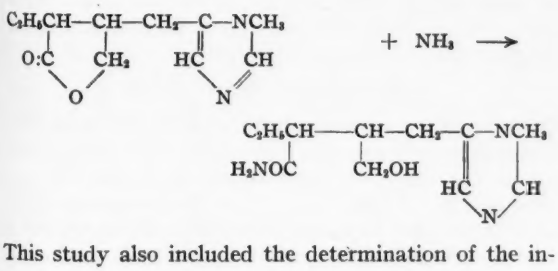
[1] For earlier papers in this series see references (*1–6*).

was measured at 50.0°C. with current densities ranging from 10^{-7} to 10^{-4} Amp./cm.^{2} in a 0.1 *N* solution of ammonium chloride in liquid ammonia. The absolute values of the overvoltage were found to be higher by 0.2 V. than those in aqueous solutions of hydrogen chloride. In the case of the mercury electrode, a difference of 0.8–0.9 V. was observed, but accurate measurements could not be made because of the formation of ammonium amalgam during electrolysis. Preliminary studies using a lead electrode showed that the overvoltage is greater in ammonia than in water, but experimental difficulties prevented the determination of accurate values. The increase in hydrogen overvoltage in liquid ammonia is attributed to the greater affinity of the ammonia molecule for the proton.

The electrolytic reduction of nitrobenzene, nitrosobenzene, phenylhydroxylamine, azoxybenzene, and azobenzene in the presence of ammonium chloride and sodium chloride in liquid ammonia has been studied by Shiba and co-workers (*18*). The reactions were carried out in a modified Baly tube with an aluminum anode, nickel cathode, and an asbestos diaphragm. The reduction products of azoxybenzene and azobenzene were identified by comparing their absorption spectra in liquid ammonia. The results of this investigation are summarized.



The rate of ammonolysis of pilocarpine in liquid ammonia has been studied at 0°, 10°, 20°, and 30° in the presence of ammonium salts including HCO_2NH_4, $C_6H_5CO_2NH_4$, $CH_3CO_2NH_4$, NH_4Cl, NH_4Br, NH_4NO_3, NH_4I, and NH_4ClO_4 at concentrations ranging from 0.1 *N* to 5 *N* by Shatenshtein and Markova (*19*). The ammonolytic reaction is believed to proceed as follows.



This study also included the determination of the influence of 2 *N* solutions of neutral salts such as sodium bromide, nitrate, iodide, and perchlorate upon the catalytic action of 0.1 *N* ammonium chloride and bromide. It was found that an increase in the acid concentration and the addition of neutral salts changed the specific activity of ammonium salts in the same manner, the catalytic activity increasing in the following order.

$$Cl^- > Br^- > NO_3^- > I^- > ClO_4^-$$

Further studies have also been made (*20*) on the influence of ammonium salts upon the rate of ammonolysis of santonin in liquid ammonia at 20°C. The rate constant was measured using solutions of ammonium salts of weak mineral acids, carboxylic acids, phenols, amides and imides of carboxylic acids, derivatives of aquo- and ammono-carbonic acids, nitroaniline, nitromethane, and carbazole. An extensive study of the acid-base properties of various indicators in neutral, acid, and basic solutions in a number of non-aqueous solvents including liquid ammonia has been made by Shatenshtein (*21*).

TABLE 2

Temperature (°C.)	20	10	0	−10	−20
Solubility (g. $NaNH_2$/1000 g. NH_3)	0.16	0.14	0.14	0.13	0.11

In the preparation of urea, in forty per cent. yield, from liquid ammonia and gaseous carbon dioxide, the heat of formation of urea has been found to be 7000 cal./gram molecule of carbon dioxide (*22*).

In an earlier review (*23*) reference has been made to the publication of Freed and Thode (*24*) concerning the non-existence of colloidal solutions of sodium in liquid ammonia.

II. INORGANIC REACTIONS

1. *Ammonation*

The triammonates of gallium and indium trifluorides have been prepared by extracting the corresponding trihydrates several times with liquid ammonia, followed by treatment with gaseous ammonia at room temperature (*25*). This procedure was necessitated by the fact that fluorides, in general, show less tendency to combine directly with ammonia than do other halides. Although some evidence of the formation of $GaF_3 \cdot 2NH_3$ and $InF_3 \cdot 2NH_3$ was obtained, the existence of these diammonates was not definitely established. The preparation of a yellow octammonate of europium dichloride, $EuCl_2 \cdot 8NH_3$, has been reported (*26*). Decomposition of this substance results in a pale yellow compound which is believed to be the monammonate.

The results of studies of the vapor tension and heat of formation of ammonates of the alkaline earth perchlorates, $Ca(ClO_4)_2 \cdot 6NH_3$, $Sr(ClO_4)_2 \cdot 7NH_3$, $Ba(ClO_4)_2 \cdot 6NH_3$, and magnesium perchlorate, $Mg(ClO_4)_2 \cdot 6NH_3$, have been reported (*27*). It was found that the heat of formation and stability increase with decrease in size of the cation.

Foster and co-workers (*28*) have shown that a num-

ber of ammino compounds are formed between triphenyl lead chloride and liquid ammonia at its boiling point. None of these compounds is stable at room temperature. The composition of the compound of highest ammonia content is believed (tentatively) to be expressed as the ratio of 1 mole of the chloride to 9.72 moles of ammonia. In no case can the composition of these compounds be expressed as the ratio of small whole numbers. Treatment of symmetrical dimethyldiborane with liquid ammonia at low temperatures has been shown to result in the formation of the diammonate, $(CH_3)_2B_2H_4 \cdot 2NH_3$ (*29*).

The influence of factors such as time, temperature, ammonia concentration, water content, and autoclave charge density, on the quantity and availability of nitrogen fixed during the ammonation of Capac (Michigan) peat by liquid ammonia has been determined (*30*). Of these factors, only time and temperature of ammonation exert appreciable effects. Maximum fixation of nitrogen was obtained by heating the peat with liquid ammonia in an autocalve for three to five hours at temperatures from 130° to 180°C.

2. *Ammonolysis*

Yellow, amorphous, silicon monochloride (prepared by the thermal decomposition of $Si_{10}Cl_{20}H_2$) has been shown to undergo ammonolysis when treated with liquid ammonia at room temperature or at temperatures below 0°C. (*31*). Ammonolysis is accompanied by liberation of hydrogen and results in complete removal of chlorine. The available evidence indicates that the monochloride, $(SiCl)_x$, is a highly polymerized substance involving very long chains of silicon atoms. Upon reaction with ammonia, rupture of the chain results in products containing chiefly six and eight atom chains and having the formulas, $Si_6(NH_2)_6(NH)_2$ and $Si_8(NH_2)_8(NH)_2$. By analogy with carbon chemistry, the structures of these substances may be represented as involving alternating double bonds, with an imino group at each end of the silicon chain.

The ammonolysis of zirconium tetrabromide by liquid ammonia at or above 0°C. has been shown to result in the formation of the ammonobasic salt, $Zr(NH)_2 \cdot 7NH_4Br \cdot 5NH_3$ (*32*). This salt is soluble in liquid ammonia in the presence of an excess of ammonium bromide. The action of potassium or potassium amide on the ammonobasic salt yielded a mixture of $Zr(NH)_2$ and $Zr(NK)_2 \cdot 2NH_3$. The latter salt was found to be ammonolyzed extensively [forming $Zr(NH)_2$] at 0° and to be converted to $Zr(NH)_2 \cdot 7NH_4Br \cdot 5NH_3$ in the presence of excess ammonium bromide.

The interaction of aminomonopersulfuric acid and liquid ammonia has been shown to result in the precipitation of ammonium sulfate and the formation of a solution possessing both oxidizing and reducing properties (*33*). The violent decomposition accompanying the evaporation of the liquid ammonia is attributed to the decomposition of free NH groups or of the unknown diazene, diimide, the formation of which is shown in the last of the following equations:

$$NH \cdot H_2SO_4 + 2NH_3 \rightarrow (NH_4)_2SO_4 + [NH]$$

$$3[NH] \rightarrow N_2 + NH_3$$

$$2H:\ddot{N}:\rightarrow H:\ddot{N}:\ddot{N}:H$$

The action of liquid ammonia at −33° on certain sulfur trioxide addition compounds [$C_5H_5N \cdot SO_3$, $C_6H_5N(CH_3)_2 \cdot SO_3$, $O(CH_2CH_2)_2O \cdot SO_3$, $HCl \cdot SO_3$, and $NaCl \cdot SO_3$] has been shown to result in the formation of ammonium sulfamate, $NH_4SO_3NH_2$, together with relatively smaller quantities of triammonium imidodisulfonate, $NH_4N(SO_3NH_4)_2$, and ammonium sulfate (*33a*). These reactions are believed to be ammonolytic in character.

Certain relationships between "solvolytic" reactions in water, amines, and liquid ammonia, and the occurrence of acid-catalyzed reactions in these solvents have been discussed (*34*).

3. *Reactions of Solutions of Metals*

The compounds commonly known as the alkali tetroxides, M_2O_4, represent the end-products of the action of oxygen on liquid ammonia solutions of the alkali metals. Helms and Klemm (*35*) have prepared the potassium, rubidium, and cesium compounds by passing oxygen gas into liquid ammonia solutions of these metals at −30° to −50° for one-half day. Study of the paramagnetism, crystal structure, and stereochemistry of these substances has led to the conclusion that they are not "tetroxides" but rather "monoalkali dioxides," MO_2. Attempts by Pierron (*36*) to prepare pure oxides of lithium by passing oxygen gas into a liquid ammonia solution of lithium until the blue color was discharged led to the formation of mixtures of Li_2O and Li_2O_2. Pierron indicates that extensive studies of modifications of experimental conditions made in an effort to secure pure Li_2O_2 were unsuccessful. Experimental procedures used by Klemm and coworkers (*37*) in the preparation of the pure monosulfides, monoselenides, and monotellurides of sodium, potassium, rubidium, and cesium have been described in considerable detail. These substances were prepared in the usual manner; *i. e.*, by interaction of the elements in liquid ammonia.

The reduction of bismuth oxyiodide in liquid ammonia at room temperature by means of sodium and potassium has been found to occur in accordance with the equation (*38*)

$$BiOI + 3M + NH_3 \rightarrow Bi + MI + MOH + MNH_2$$

The use of excess alkali metal resulted in the formation of bismuthides. The reaction between bismuth oxyiodide and potassium amide in liquid ammonia at room temperature yielded bismuth oxyamide,

$$BiOI + KNH_2 \rightarrow BiONH_2 + KI$$

Under similar experimental conditions, silver oxide and bismuth trioxide are reduced to the corresponding metals by the action of liquid ammonia solutions of potassium (*39*). Cupric oxide is reduced to cuprous oxide while the latter is reduced to elemental copper to a limited extent. Germanic oxide, GeO_2, is not acted

upon either by potassium or by potassium amide in liquid ammonia.

The reaction between phosphine and calcium in liquid ammonia at −70° has been shown (*40*) to proceed as indicated by the equation,

$$2PH_3 + Ca + xNH_3 \rightarrow Ca(PH_2)_2 \cdot nNH_3 + H_2 + (x - n)NH_3$$

The ammonate, $Ca(PH_2)_2 \cdot 6NH_3$, decomposes at 0°C. with formation of a diammonate. Both of these substances are spontaneously inflammable in air.

Foster and co-workers (*41*) have shown that hexaphenyldilead, $(C_6H_5)_3Pb-Pb(C_6H_5)_3$, may be prepared readily by the reduction of triphenyl lead iodide with sodium, or by the reduction of triphenyl lead chloride with tetrasodium nonaplumbide, Na_4Pb_9, in liquid ammonia at −33°C. No evidence of reaction resulted from the addition of ammonium bromide to a liquid ammonia solution of sodium triphenylplumbide, $(C_6H_5)_3PbNa$.

The disodium salt of sulfamic acid, $NaNHSO_2ONa$, has been formed by the reaction of sulfamic acid with excess sodium in liquid ammonia (*42*). The sulfamates, $M(OSO_2NH_2)_3 \cdot xH_2O$, of La, Nd, Sm, and Y, have been found to be insoluble in liquid ammonia (*43*).

III. ORGANIC REACTIONS

1. *Ammonolysis*

The ammonolysis of the methyl ester of α-hydroxy-(2,4,6-trimethylbenzoyl) valeric acid has been found to result in the formation of the corresponding amide, $(CH_3)_3C_6H_2CO(CH_2)_3CH(OH)CONH_2$, in nearly quantitative yield (*44*). The reaction was carried out by allowing the ester to react with liquid ammonia in a sealed tube over a period of four days at room temperature. The ammonolysis of fatty oils has been investigated by Audrieth and co-workers (*45*). Olive, cottonseed, maize, soybean, castor, linseed, perilla, and tung oils and pork lard were ammonolyzed to mixtures of the corresponding fatty acid amides by liquid ammonia at 25°, both in the presence and absence of ammonium chloride (an acid catalyst). To a considerable degree, this work duplicates the earlier investigations of Shatenshtein and Israilevic (*46*).

The production of acid amides by the action of liquid ammonia on lactones has been reported for the following cases: *d*-α,α-mannooctonic lactone (*47*), 2,3,4-trimethyl *d*-mannonolactone (*47a*), 4,6-dimethyl-*d*-galactonolactone (*48*), 2,4,6-trimethyl-*d*-iodono-δ-lactone (*49*). The polymer prepared by the action of a boron fluoride-ether complex on α-angelica lactone has been found to react with a mixture of dioxane and liquid ammonia at 150–160° to form a polylactam (*50*).

Marvel and Dunlap (*51*) have shown that the action of liquid ammonia on vinyl chloride polysulfone causes the complete removal of the chlorine and the partial removal of sulfur dioxide.

The rates of reaction between dimethylketone, methylpropylketone, methylphenylketone, 1-methyl-cyclohexan-3-one, 1-methyl-cyclohexan-4-one, benzaldehyde, and liquid ammonia at 0° and atmospheric pressure have recently been measured (*52*). It was found that the rates of reaction are primarily dependent upon the electrochemical character of the radical, with stearic hindrance being a factor of secondary importance.

The ammonolysis of 2,4,6-tribromopyridine by liquid ammonia in a sealed tube at 130°C. over a period of twenty-four hours has been shown to result in the formation of 2,6-diamino-4-bromopyridine together with a small quantity of an amino-dibromopyridine (*53*). Small and Palmer (*54*) have reported that the action of liquid ammonia on α-chlorocodide results in the loss of the halogen atom in the 6-position and the substitution of an amino group in the 8-position. The reaction was carried out in a sealed tube over a period of twenty-four hours at 50°C. Under similar conditions, the corresponding bromo compound was relatively unreactive and most of the starting material was recovered unchanged. The addition of ether solutions of hexynyl magnesium halides (*55*) to liquid ammonia has been shown to result in the formation of amorphous white precipitates. The composition of these materials is illustrated by the formula $C_4H_9C{\equiv}CMg \cdot NH_2 \cdot 2MgX_2 \cdot Mg(NH_2)_2 \cdot 6NH_3$. Allen and Henze (*56*) have found that 4-chloro-4-ethoxymethylheptane is unreactive toward both liquid ammonia at −33.5° and solutions of sodium amide in ammonia at the same temperature. Bisbromopentaerythritol does not react with liquid ammonia at room temperature (*57*). At 100°C., however, there occurs a reaction leading to a mixture from which no definite product has been obtained. Dioxaspiroheptane is not attacked by liquid ammonia at 100°, but is decomposed completely at 200°.

2. *Reactions of Solutions of Metals*

The reduction of diethyltin, triethyltin, tetraethyltin, diethyltin bromide, triethyltin bromide, and triethyltin hydroxide by means of liquid ammonia solutions of sodium has been investigated (*58*). In the course of this study, the following reactions were carried out:

$$(C_2H_5)_2Sn + 2Na \rightarrow (C_2H_5)_2SnNa_2$$
$$2(C_2H_5)_2Sn + 2\,Na \rightarrow (C_2H_5)_2Sn(Na)Sn(Na)(C_2H_5)_2$$
$$(C_2H_5)_3Sn + Na \rightarrow (C_2H_5)_3SnNa$$
$$(C_2H_5)_3SnNa + C_2H_5Br \rightarrow (C_2H_5)_4Sn + NaBr$$
$$(C_2H_5)_4Sn + 2Na \rightarrow (C_2H_5)_3SnNa + C_2H_5Na$$
$$(C_2H_5)_2SnBr_2 + 2Na \rightarrow (C_2H_5)_2Sn + 2NaBr$$
$$(C_2H_5)_3SnBr + Na \rightarrow (C_2H_5)_3Sn + NaBr$$
$$(C_2H_5)_3SnOH + Na \rightarrow (C_2H_5)_3Sn + NaOH$$

By similar reactions, Gilman and Bailie (*59*) have prepared a number of organolead compounds. The reactions employed are illustrated by the following equations, in which *R* represents an aryl or substituted aryl group:

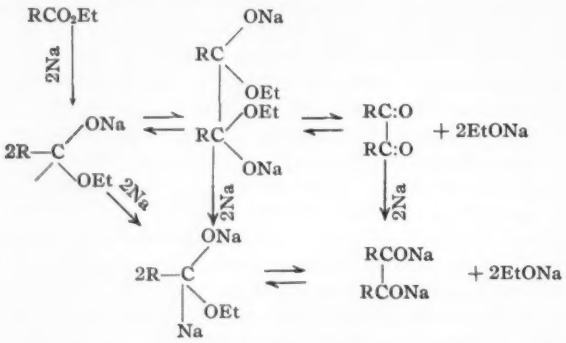
$$R_3PbX + Na \rightarrow R_3Pb + NaX$$
$$R_3PbX + 2Na \rightarrow R_3PbNa + NaX$$
$$R_3PbNa + RX \rightarrow R_4Pb + NaX$$

Attempts to prepare substituted lead hydrides of the type, R_3PbH, by means of the reaction

$$R_3PbNa \xrightarrow{[NH_4Br]} [R_3PbH]$$

were unsuccessful. The products obtained were trivalent organolead compounds, lead bromide, and RH compounds.

The action of sodium in liquid ammonia on esters such as ethyl isobutyrate, ethyl benzoate, and ethyl trimethylacetate has been studied by Kharasch and co-workers (*60*). They have suggested the following scheme as an explanation of the mechanism of the reduction of esters by sodium.



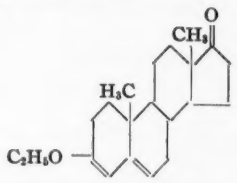
A study of the reduction of 2,3-diphenylbutadiene (*61*) has shown that this substance, when dissolved in a mixture of ether and liquid ammonia at its boiling point and treated with a liquid ammonia solution of sodium, reacts to form *meso*-2,3-diphenylbutane in fifty-five per cent. yield, together with an aromatic oil and a small amount of a solid product believed to be a bimolecular reduction product.

The preparation of dimethylacetylene in eighty per cent. yield from sodium acetylide, sodium amide, and methyl sulfate in liquid ammonia at −80°C. has been reported (*62*). Attempts to prepare this substance from sodium methylacetylide and methyl sulfate gave unsatisfactory yields. In the course of studies on metalation, Gilman and Bebb (*63*) have shown that ethynylsodium and ethynylpotassium fail to metalate 1-heptyne to any appreciable extent. Ethynyl sodium was found to metalate phenylacetylene, while slight metalation occurred with heptynylsodium and phenylacetylene. These experiments indicate the following order of decreasing acidity:

$$C_6H_5C{\equiv}CH > C_5H_{11}C{\equiv}CH > HC{\equiv}CH$$

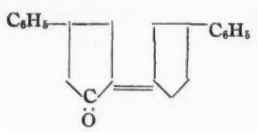
Pregnenin-17-ol-3-one

has been prepared by adding a benzene-ether solution of the 3-enol ethyl ether of androstenedione

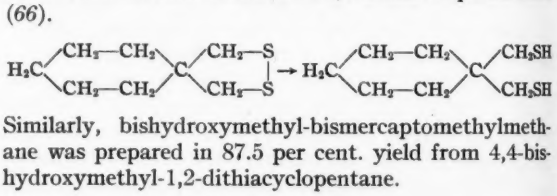


to a solution of potassium acetylide in liquid ammonia followed by de-etherification (*64*).

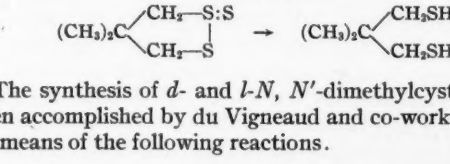
An attempt to introduce a carbomethoxy group into 3-phenylcyclopentanone by the action of ethyl chloroacetate on the product obtained from 3-phenylcyclopentanone and sodium in liquid ammonia was unsuccessful (*65*). The reaction product proved to be a mixture of unchanged ketone and phenylcyclopentylidene-(phenyl)-cyclopentanone,



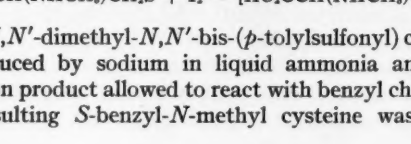
A ninety-three per cent. yield of 1,3-dimercapto-2,2-pentamethylenepropane has been obtained from the reaction between a solution of sodium in liquid ammonia and an ether solution of 2,3-dithia-5-spirodecane (*66*).



Similarly, bishydroxymethyl-bismercaptomethylmethane was prepared in 87.5 per cent. yield from 4,4-bishydroxymethyl-1,2-dithiacyclopentane.



Treatment of an ether solution of 4,4-dimethyl-1-thio-1,2-dithiacyclopentane with sodium in liquid ammonia has been found to result in a ninety-four per cent. yield of 1,3-dimercapto-2,2-dimethylpropane.



The synthesis of *d*- and *l*-*N*, *N'*-dimethylcystine has been accomplished by du Vigneaud and co-workers (*67*) by means of the following reactions.

$$[HO_2CCHN(CH_3)(SO_2C_6H_5)CH_2]_2S_2 + Na \rightarrow HO_2CCH(NNCH_3)CH_2SNa$$

$$HO_2CCH(NHCH_3)CH_2SNa + C_6H_5CH_2Cl \rightarrow HO_2CCH(NHCH_3)CH_2SCH_2C_6H_5$$

$$HO_2CCH(NHCH_3)CH_2SCH_2C_6H_5 + Na \rightarrow$$

$$HO_2CCH(NHCH_3)CH_2S + I_2 \rightarrow [HO_2CCH(NHCH_3)CH_2]_2S_2$$

Thus, *N*,*N'*-dimethyl-*N*,*N'*-bis-(*p*-tolylsulfonyl) cystine was reduced by sodium in liquid ammonia and the reduction product allowed to react with benzyl chloride. The resulting *S*-benzyl-*N*-methyl cysteine was then

treated with sodium in liquid ammonia and the *N*-methylcysteine so formed was oxidized to the disulfide by the addition of a solution of iodine in ether. *dl*-Cystine has been prepared in eighty per cent. yield by the reduction of *S*-benzyl-*dl*-cysteine with sodium in liquid ammonia, followed by oxidation of the resulting sodium cysteinate (*68*),

$$HO_2CCH(NH_2)CH_2SCH_2C_6H_5 + 2Na \rightarrow$$
$$HO_2CCH(NH_2)CH_2SNa \xrightarrow[HOH]{[O]} [HO_2CCH(NH_2)CH_2]_2S_2$$

S-Benzyl-*l*-cysteine has been obtained in eighty-five per cent. yield by the reduction of *l*-cystine with sodium in liquid ammonia followed by the addition of benzyl chloride to the reduction product (*69*),

$$[HO_2CCH(NH_2)CH_2]_2S_2 + 2Na \rightarrow$$
$$2HO_2CCH(NH_2)CH_2SNa + C_6H_5CH_2Cl \rightarrow 2HO_2CCH(NH_2)CH_2SCH_2C_6H_5$$

By reduction of *S*-benzyl-*d*-cysteine with sodium in liquid ammonia followed by oxidation of the reduction product there was obtained an eighty-six per cent. yield of *d*-cystine.

$$HO_2CCH(NH_2)CH_2SCH_2C_6H_5 + Na \rightarrow$$
$$NaO_2CCH(NH_2)CH_2SNa \xrightarrow[HOH]{[O]} [HO_2CCH(NH_2)CH_2]_2S_2$$

S-Benzyl-*l*-cysteine has been prepared by reduction of cystine with sodium in liquid ammonia followed by addition of benzyl chloride (*70*).

The reduction of both β-geraniol and β-linaloöl has been shown to result in the formation of β-methylgeraniolene (*71*). The reactions were initiated at temperatures considerably below the boiling point of the solvent by adding an absolute alcohol solution of β-geraniol or β-linaloöl to a solution of sodium in liquid ammonia. After volatilization of the ammonia, the reduction products were treated with water. An unsuccessful attempt has been made to separate geraniol and citronellol through the reduction of the geraniol by means of sodium in ammonia (*72*).

The reduction of a number of unsaturated and polynuclear aromatic hydrocarbons by means of solutions of sodium and calcium in liquid ammonia has been studied by Hückel and Bretschneider (*73*). Most of these reactions were carried out at temperatures within the range $-75°$ to $-60°$C., although in a few cases higher temperatures (up to $-33.5°$) were employed. The use of ether as a diluent was found advantageous since it facilitated the solution of the hydrocarbon materials and permitted more accurate temperature control. As has been observed in earlier studies of reactions of this type, the primary reduction products frequently consist of alkali or alkaline earth metal salts which form colored solutions in ammonia. Upon completion of the primary reduction process, these salts were treated (in liquid ammonia) with ammonium chloride. Only in the case of 1,4-diphenylbutadiene did there appear to be any marked difference between the products obtained with sodium and those resulting from reactions involving calcium. In the first column of Table 3 there are listed the hydrocarbons reduced and in the second column the products identified.

TABLE 3

Hydrocarbon	*Product(s)*
Naphthalene ($-75°$ to $-65°$)	Δ^2-Dihydronaphthalene
Naphthalene ($> -65°$)	Δ^1- and Δ^2-Dihydronaphthalene
Naphthalene ($-33.5°$)	Δ^1- and Δ^2-Dihydronaphthalene
Δ^2-Dihydronaphthalene	Δ^1-Dihydronaphthalene
Δ^1-Dihydronaphthalene	Tetralin
Biphenyl	3,4-Dihydrobiphenyl
3,4-Dihydrobiphenyl	3,4,5,6-Tetrahydrobiphenyl
Terphenyl	3,4-Dihydroterphenyl and a compound, $C_{18}H_{14}$
3,4-Dihydroterphenyl	A red compound
1,4-Diphenylbutadiene	Mixture of solid and liquid hydrocarbons
Diphenylmethane	An unsaturated hydrocarbon
9,10-Diphenylanthracene	(Starting material recovered)
Phenanthrene	1,2,3,4-Tetrahydrophenanthrene
Butadiene	Butene, octadiene

It is also reported that upon reaction with a solution of sodium amide in liquid ammonia at $-70°$, Δ^2-dihydronaphthalene is converted quantitatively to Δ^1-dihydronaphthalene.

In connection with their studies on the origin of formaldehyde obtainable from lignin, Freudenberg and co-workers (*74*) have found that formaldehyde cannot be obtained from lignin which has been pretreated with a liquid ammonia solution of potassium in a sealed tube over a period of fifteen hours at 20°C. That the methylenedioxy groups in lignin are aromatic in character is indicated by the fact that certain aromatic methylenedioxy compounds behave similarly toward potassium in ammonia under comparable experimental conditions. Thus, when dihydrosafrole was treated with a solution of potassium (and potassium amide) for twenty-four hours at room temperature, it was converted to *p*-hydroxyphenylpropane. Piperonylic acid similarly treated for fifteen hours at 15–20° yielded *m*-hydroxybenzoic acid. This and other evidence leads to the conclusion that the formaldehyde obtainable from lignin is present largely in aromatic methylenedioxy groups.

The use of liquid ammonia as a medium for the formation of cellulose xanthates has been investigated (*75*). Trisodium cellulose was prepared by the interaction of sodium and cellulose in liquid ammonia and thereafter treated with carbon bisulfide in the same solvent. The formation of the sodium salt was accelerated by the presence of sodium halides, and the reaction with carbon bisulfide was accelerated by the presence of sodium nitrate. The xanthates produced in this manner were soluble in water.

The reaction between 2,3,4-trimethyllevoglucosan and sodium in liquid ammonia has been shown to result in the formation of phenol (*75a*). Thus, 0.55 gram of phenol was obtained from 3.86 grams of the carbohydrate in a reaction carried out in a sealed tube at room temperature over a period of 18 days.

The behavior of insulin toward sodium in liquid ammonia has been shown to be similar to that of casein, egg albumin, edestin, and silk fibroin (*76*). With respect to its action in lowering blood sugar, insulin was found to be inactivated completely by treatment with small amounts of sodium. Crystalline insulin after

being dried at 80°C. was found to be soluble in liquid ammonia without appreciable change. Miller and Roberts (*77*) have studied the behavior of a number of peptones and related substances toward sodium in liquid ammonia. It was found that peptones in liquid ammonia are more acidic than diketopiperazine, but less acidic than proteins or amino acids. This study indicates that peptones contain relatively more diketopiperazine than do proteins.

3. *Other Organic Reactions*

Kharasch and Sternfeld have shown that sodium amide in liquid ammonia may be used successfully as a condensing agent in the preparation of hexatriene and its polymers from allyl chloride (*78*).

$$H_2C{:}CHCH_2Cl + ClCH_2CH{:}CH_2 \xrightarrow{NaNH_2} H_2C{:}CHCH{:}CHCH{:}CH_2$$

The formation of hexatriene was accompanied by the production of high boiling products in quantities dependent upon the particular experimental conditions employed. Thus, in one instance there was obtained a fifty per cent. yield of 1-chloromethyl-2-vinylcyclohexene-3. The polymerization of hexatriene is believed to be promoted by high concentrations of sodium amide.

It has been observed that no reaction occurs between thiourea and 2-chlorobenzothiazole in liquid ammonia at −33.5° or at room temperature either in the presence or absence of ammonium bromide (*79*). Both compounds, however, enter into reaction with the solvent under the above conditions.

Roberts and Horvitz (*80*) have used liquid ammonia in the preparation of conjugation products of epinephrine with glycine, tyrosine, glutamic acid, urea, lactic acid, dextrose, cholesterol, and vitamin C. The physiological activity (increase in blood pressure) of all of the products excepting that with vitamin C was greater than that of epinephrine.

IV. PATENTS

A number of patents issued during the year relate to the preparation of derivatives of cellulose and to the treatment of various cellulosic materials. Peterson and Barry have patented methods for the preparation of cellulose ethers. One process involves the formation of sodium cellulose by the treatment of cellulose with sodium (*81*) in liquid ammonia at its boiling point in the presence of an inert hydrocarbon diluent such as toluene, followed by the addition of, for example, ethyl bromide. A similar process differs to the extent that the alkali cellulose is formed by the interaction of cellulose and an alkali amide (*82*), such as sodium amide, in liquid ammonia followed by volatilization of ammonia and by etherification in a solvent such as toluene. The extent of salt formation is governed by the quantity of alkali amide used. The use of alkali cellulose formed from cellulose and an alkali metal in liquid ammonia has also been suggested in a method for the preparation of aminocellulose derivatives (*83*). The alkali cellulose so formed is subsequently treated with a monohaloamine.

In another patented process, products such as cellulose acetobutyrate (*84*), cellulose acetate stearate (*85*), cellulose acetate propionate (*86*), or other saturated fatty acid esters of cellulose (*87*) are stabilized by treatment with and subsequent separation from anhydrous liquid ammonia. This method has also been applied in the stabilization of cellulose acetate and carbohydrate derivatives such as starch stearate (*88*). The separation of cellulose diacetate from insoluble cellulose triacetate (*89*) has been accomplished in a process which depends upon the solubility of the former in liquid ammonia in the presence of an acid catalyst. The product obtained by the interaction of phosphorus pentoxide and liquid ammonia has been used to impregnate cellulosic materials such as textile fibers, paper, or regenerated cellulose for the purpose of producing flameproof products (*90*).

As has been true for a number of years, a considerable number of patents issued on processes involving the use of liquid ammonia center about the problem of preparing organic nitrogen compounds such as amides, amines, nitriles, and so forth. Thus, formamide is formed from carbon monoxide and liquid ammonia in the presence of a suitable catalyst at temperatures between 70° and 100° and pressures ranging between 30 and 90 atmospheres (*91*). Acid amides and glycerol are produced by treating fats with liquid ammonia in the presence of ammonium salts, inorganic acids, or metal amides at 20–40° and under pressures of 8 to 15 atmospheres (*92*). Amino nitriles are prepared from hydroxy nitriles such as formaldehyde cyanohydrin by treatment with liquid ammonia under pressure at 75–80°C. (*93*). A method for the production of melamine (2,4,6-triamino-1,3,5-triazine) involves the action of liquid ammonia under pressure at elevated temperatures on cyanamide, ammonium thiocyanate, methylsulfocyanurate, cyanuric chloride (*94*), or dicyanodiamide (*94*, *95*). In another process, trichloroacetamidine (*96*) is formed by treating trichloroacetonitrile with an excess of liquid ammonia at −40°C. Other related compounds and their derivatives may be prepared similarly. Ammonium imidosulfonate and ammonium amidosulfonate (*97*) are formed by introducing liquid ammonia and sulfur trioxide into a suitable reaction chamber maintained at an elevated temperature. The use of an excess of ammonia is specified. Reaction in liquid ammonia is involved in a process requiring the formation of sulfonamides which are subsequently converted to the corresponding chloromethyl compounds (*98*). Thus, octadecylsulfonamide is formed by the reaction between liquid ammonia and octadecylsulfonyl chloride.

A patent issued to Miller and Roberts (*99*) and assigned to the du Pont Company is of interest. This patent, concerned with a process for the "production of finely divided sodamide," was applied for under date of September 13, 1934, and issued as of June 20, 1939. A method accomplishing essentially the same result was

described in a paper submitted by Nieuwland and coworkers (*100*) under date of July 2, 1934, and published in October of the same year. The process involves the formation of sodium amide by the reaction between sodium and liquid ammonia at its boiling point in the presence of a catalyst consisting of a compound of iron. The authors quote from the patent, "Table 2 lists the compounds of iron which we have found to catalyze the reaction between sodium and anhydrous liquid ammonia. They show their catalytic effect *without the presence of metallic iron.*" One of the compounds listed is ferric nitrate. The earlier work of Loane (*101*) as well as that of Nieuwland and coworkers (*100*) has shown that ferric nitrate is reduced to finely divided and highly reactive metallic iron under the experimental conditions disclosed in the patent. This, together with other evidence (*102*) would tend to indicate that in cases involving the use of an iron compound as a catalyst for the reaction in question, *satisfactory* catalytic action results from the presence of metallic iron formed by the reduction of the iron compound employed.

The removal of water and impurities such as chlorides and chlorates from aqueous alkali metal hydroxides (*e. g.*, NaOH) has been accomplished by a process involving extraction of the material to be purified with liquid ammonia (*103*). Either anhydrous ammonia or mixtures of liquid ammonia and limited quantities of water may be used. Patents have been issued on methods for producing improved nitrate explosives consisting of a finely divided sensitizer such as aluminum, sulfur, or dinitrotoluene (*104*) or nitrostarch (*105*) uniformly dispersed in solid ammonium nitrate. The dispersion is effected by suspending the sensitizer in a liquid ammonia solution of ammonium nitrate and thereafter evaporating the solvent ammonia. Another patent relates to the use of liquid ammonia in the production of mixtures of ammonia, hydrogen, and nitrogen which are suitable for use as fuels for internal combustion engines (*106*).

V. GENERAL

In designing an apparatus for the dispensing of dry gaseous or liquid ammonia, advantage has been taken of the marked deliquescence of ammonium thiocyanate in the presence of gaseous ammonia (*107*). The gas from the commercial cylinder is absorbed in dry ammonium thiocyanate and thereafter liberated, as needed, by the application of heat. The necessary apparatus is described in detail.

The second in a series of monographs by Shatenshtein (*108*) has appeared within the year. This volume is concerned with experimental procedures which are available for the utilization of liquefied gases as solvents and reaction media, and includes a bibliography on the solubility of inorganic substances in liquid ammonia. Those portions of the book which deal with electrochemical methods were written by V. A. Pleskov.

Wildt (*109*) has suggested that the atmosphere of the planet Jupiter consists largely of ammonia and that certain colored bands may be due to the formation of solutions of sodium in ammonia while other bands are attributed to the presence of sodium amide, which results from the reaction between sodium and ammonia.

Certain interesting relationships between the solubility of intermetallic compounds in molten salts and in liquid ammonia have been pointed out by Heymann and Weber (*110*). Properties of liquid ammonia solutions in their relationship to basic problems in electrochemistry have been discussed by Frumpkin and Pleskov (*111*).

ACKNOWLEDGMENT

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BUSINESS MEETING OF THE DIVISION OF CHEMICAL EDUCATION

At the business meeting of the Division held April 10th, the Secretary reported the action taken at the meetings of the Board of Publication and of the Executive Committee, and Dr. H. N. Alyea, Chairman of Committee on Nomenclature, stated that their work had been completed and the committee should be discharged. It was so ordered, and a vote of appreciation given for its work. PAUL H. FALL, *Secretary*

MICROCHEMICAL KITS

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DIFFERENT types of boxes or blocks have been proposed for reagents and equipment for chemical microscopy and microchemical qualitative analysis (*27*, *28*, *29*, *30*, *31*, *32*, *33*, *34*, *35*, *36*), and several are available from supply houses in this country.[1]

For the past ten years it has been necessary for the writer to keep his microchemical equipment so that it could be moved readily about the building in order to protect it from loss and dirt. The first improvement over the original pasteboard box was made by fitting a frame inside a cigar humidor[2] to support a reagent block holding sixty reagents (*37*) for chemical microscopy (Figure 1). The space under the block was used for small apparatus, and eight "cobalt" bottles[3] for solutions fit in blocks around two sides of the reagent block. When the box had to be transported for any considerable distance a luggage carrier, consisting of a handle and two straps, was used. Although this arrangement proved satisfactory for a limited amount of equipment it soon became inadequate as additions were made. The field kits of Putnam, Roberts, and Selchow (*38*) seemed to meet the requirements better than other types described but they had been made up locally[4] and were not regularly available on the market.

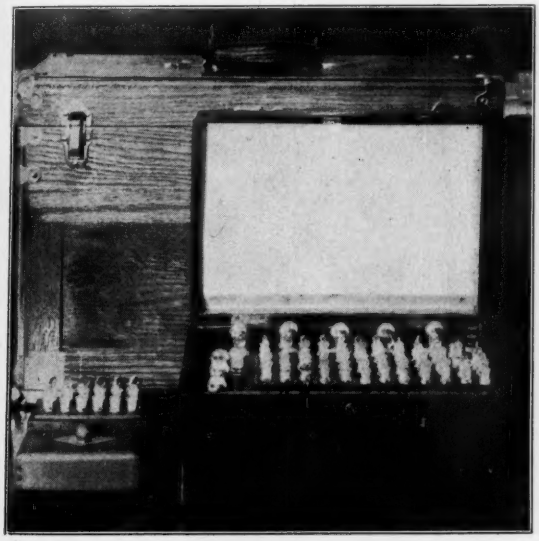

FIGURE 1

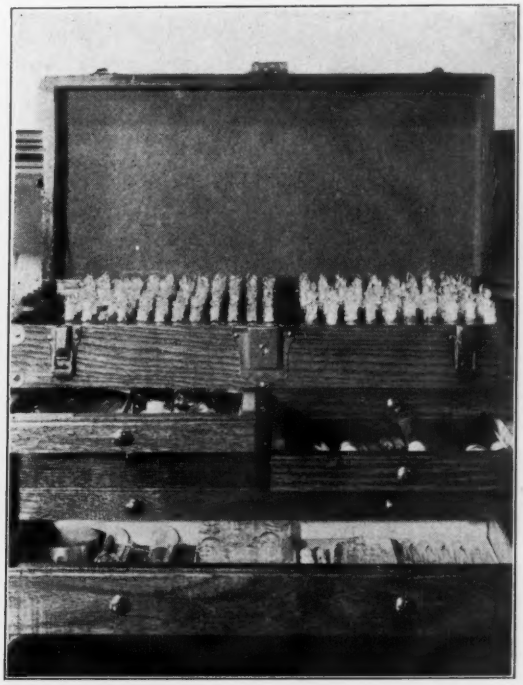

FIGURE 2

For the past five years a machinist's chest (Figures 1, 2, and 3), thoroughly painted inside and out with a high-grade spar varnish, has been giving excellent service. The upper part of the chest holds the reagents and the construction is such that the apparatus contained in the drawers below is completely isolated from the reagents in the top of the chest. As shown in Figure 2 the reagent vials fit into five blocks. Four of the blocks hold two hundred twenty glass-stoppered vials[5] and the fifth holds six ebonite vials[6] for compounds

[1] R. P. Cargille, New York City, No. 220; Eimer and Amend, New York City, No. 26098, 28357, 28358; Microchemical Service, Douglaston, N. Y., No. 1280, 1530, 1540, 1550; E. H. Sargent and Company, Chicago, No. S-46525; and Will Corporation, Rochester, N. Y., No. 14622, 14627, 14633, 14634, 18502.

[2] Suggested by one of the writer's associates at the University of Pennsylvania.

[3] Arthur H Thomas Company, Philadelphia, No. 2252.

[4] Private communication, Roberts, February, 1934.

[5] Microchemical Service, Douglaston, N. Y., No. 3790; Arthur H. Thomas Company, Philadelphia, No. 9800, 2-ml.; Will Corporation, Rochester, N. Y., No. 14632.

[6] Microchemical Service, Douglaston, N. Y., No. 3800.

of fluorine and reagents for sodium. Most of these blocks were on hand when the chest was purchased and offer no advantage over a single large one, the use of which would increase the capacity by at least thirty-three vials. Rather than employ a key chart, as is usually suggested, it has been found more convenient to put small labels on each vial, paint the labels with a clear lacquer, and arrange the reagents alphabetically.

FIGURE 3

The location of the vials is soon learned from using them, and no difficulty is experienced in finding quickly a particular reagent. Moreover, the labeled vials may be transferred without confusion to other blocks when relatively small numbers are being used, as, for example, in procedures such as those of Davison (*7*) or Short (*21*), or even procedures which require a somewhat larger number, as those of Burkhard (*3*), Kramer (*16*), or Staples (*22*). The small box shown in Figure 1, which was made by removing the partition from a playing-card box and inserting a block having holes for twelve reagent vials, has proved quite convenient when studying procedures which do not require a large number of solid reagents, and the cover offers protection from dust when the reagents are not being used. Small blocks without covers, bored for one, three, and five vials (Figure 3), are used to hold temporarily reagents which will be used repeatedly during a single working period.

Most of the reagents in the chest are solids. Reagents which sublime readily or give off fumes are kept in sealed tubes or the glass-stoppered vial is placed in a second larger vial with a tightly fitting plastic screw cap. The vials contain not only the solid reagents required for carrying out qualitative tests according to

FIGURE 4

microchemical procedures recommended by various authors (*1, 2, 3, 4, 5, 7, 8, 9, 10, 13, 16, 17, 19, 20, 21, 22, 26*), but also reference material, including compounds of most of the rare elements as well as all the more common ones, which may be used for making comparison or check tests. Some sugars, starches, and fibers are also included, but permanent slides make up the greater part of the reference material for the last two.

With the exception of some reagents for spot tests (*7, 11, 12, 14, 15, 18, 23, 24, 25, 26*), solutions are kept in 15-ml. bottles which have ground-in droppers[7] and fit into wooden blocks (Figure 3). The bottles which do not have extra caps with ground joints have the

[7] Arthur H. Thomas Company, Philadelphia, No. 2252, 2255

neck and dropper covered with a shortened test-tube, or glass tumblers are placed over the whole bottle. It is highly improbable that other people doing work of this kind will be in a place so dirty as the location of the writer, and he can recommend these precautions against dirt as having served under the worst conditions.

Solutions of some of the reagents for spot tests have been kept satisfactorily in dropping bottles with plastic

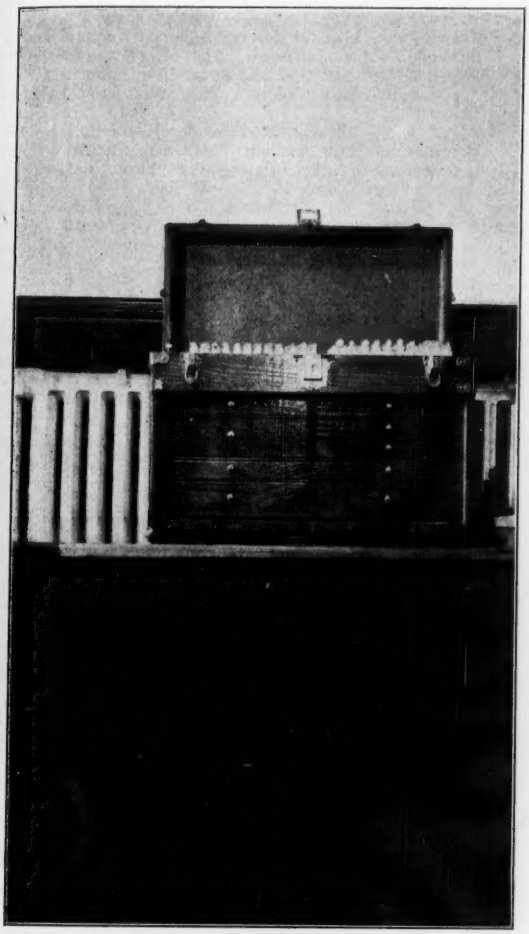

FIGURE 5

screw caps[8] and vials with applicator rods.[9] Blocks containing these vials will fit in the chest and may be kept there if a reduction is made in the number of solid reagents.

The material kept in the drawers of the chest (*Cf.*, Figure 2) includes most of the special equipment required for inorganic qualitative microanalysis on the microscope slide, in capillaries or centrifuge cones, and by spot tests, as well as that for separations and preparative work on the micro scale. No provision is made in the chest for the microscope, which is best kept and transported in its special case, or for standard apparatus found in every laboratory.

The chest as described represents a sizable investment, but the equipment gradually accumulated over such a long period of time, as one microchemical procedure after another was studied, that it has not proved embarrassing even to a college instructor's income. Moreover, it has a larger capacity and greater flexibility than microchemical boxes on the market, and at the same time its construction is much stouter and the proportionate cost is less. The writer prefers vials as described for reagents in the chest, but the cost may be lowered considerably by using screw-cap vials[10] or still more by using serological test-tubes[11] with corks, such as he uses in large numbers for storing specimens or chemicals which are rarely used and are not of the highest purity. He has been informed by people who have used the screw-cap vials for several years that they have been satisfactory, and he also knows of instances in which corked vials have been used for student instruction with apparent satisfaction.

The microscope stand shown in Figure 3, including the mirror, was obtained a number of years ago from a laboratory supply house for $2.50. New strain-free 32-mm. and 16-mm. objectives and a 10× eyepiece, which may be used with any good polarizing microscope, brought the total cost of the microscope to $21.50. Used optics would have brought the cost even lower. Such an outfit, even though supplemented with "Polaroid," is not to be considered in place of a good polarizing microscope, but is shown just to indicate at what small cost a microscope with good optics and suitable for a great deal of work can be obtained. The stand is small and much more comfortable to use than the newer larger stands, and the writer always uses it unless he needs polarized light or high magnification for which the fine adjustment is no longer sensitive enough nor the illumination satisfactory.

The two single-hole blocks of equal weight (Figure 3) are used to balance centrifuge cones because the latter vary in weight so much that a balance is not obtained merely by adding equal volumes of liquid to each tube. The oil-can microburner shown in the same figure has been described elsewhere (*6*).

[8] Arthur H. Thomas Company, Philadelphia, No. 2248-B; Wilkens-Anderson Company, Chicago, No. W-1130, W-7905, W-7906.

[9] Central Scientific Company, Chicago, No. 10555; Fisher Scientific Company, Pittsburgh, No. 20-095, 50 × 19 mm.; Arthur H. Thomas Company, Philadelphia, No. 2253-C, 50 × 19 mm.

[10] E. H. Sargent and Company, Chicago, No. S-46535; Arthur H. Thomas Company, Philadelphia, No. 9802-E, 2-ml.

[11] Fisher Scientific Company, Pittsburgh, No. 14-925.

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(37) Reference 5, p. 401.
(38) Reference 19, p. 96.

VALENCE BLOCKS *for* TEACHING INORGANIC CHEMISTRY FUNDAMENTALS

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PROBLEMS of valence, ionization, molecular weights, chemical reactions, the structure of acids, bases, and salts, and so forth, are difficult fundamentals which the average high-school chemistry student has to overcome in order to achieve success in chemistry. Any teaching device which helps to visualize these difficult units or topics is apt to be of service to teacher and pupil. Jigsaw puzzles are still popular, and chemistry students may now learn while playing, merely by fitting blocks together and reading the equations, formulas, valence, ionization, and molecular weights, and so forth, so formed. The blocks may be made of stiff paper, compressed paper, cardboard, and thin, or three-ply wood. Small sets may be used by pupils and large cardboard sets pinned on a board for teacher-demonstration purposes. These blocks were recently granted a United States patent right as a teaching device in chemistry.[1]

[1] Demonstrated before the Division of Chemical Education at the ninety-seventh meeting of the A. C. S., Baltimore, Md., April 4, 1939.

(1) GENERAL PLAN OF THE BLOCKS

Circles represent positive valences, *e. g.*, Na, H, K, Ag, Ca, Ba, Al, and so forth.

Squares represent negative valences, *e. g.*, OH, Br, Cl, I, SO_4, SO_3, PO_4.

Triangles represent positive ion valencies which have more than one valence, *e. g.*, Fe, Au, Cu.

Rectangles represent elements having both positive and negative valences such as S, N, As, and so forth.

White ovals represent organic radicals such as CH_3, C_2H_5, C_3H_5, and so forth.

The number of arms on the blocks represents the valences, one, two, or three, and so forth. In positive elements and radicals, the arms point right, having arrows at the ends, while the negative ion elements have radical arms pointing left with slots at each end. By analogy with the litmus reaction the deeper colors, red and blue, are assigned to the more active elements or radicals. The lighter colors, pale blue and pink, represent the less active elements or radicals. The blocks may be kept in separate receptacles corresponding to the valences.

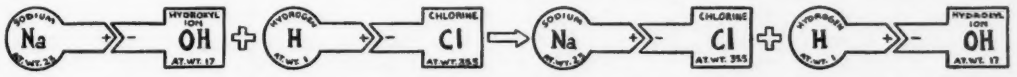

FIGURE 1

(2) USES FOR MAKING FORMULAS

To make a chemical formula the student merely fits together the blocks necessary to its completion like a jigsaw puzzle. First the student might arrange his separate sets of blocks, correlating them with the lessons in his chemistry text, in order to learn the valences, ionization, and so forth, of the common elements and compounds.

(3) MONOVALENT FORMULAS

To familiarize the student gradually with the blocks as teaching aids, he might pick out a blue circle and any red square with one arm each and fit them together, for example, sodium and chlorine. The sodium, Na, as will be noted, carries a positive charge and the chlorine, Cl, a negative one. The combined atomic weights 23 + 35 of sodium chloride are observed on each block and added up to make 59. The blocks are colored various shades of red and blue, combinations of the darker shades representing the more stable compounds. The metals with positive arms, colored blue, tend to form bases turning red litmus to blue. Hydrogen, it should be noted, while not a metal, acts like one. The non-metal blocks have negative arms and tend to form acids turning blue litmus red. Dark shades combined with light indicate unstable compounds, *e. g.*, Na_3PO_4. The three Na blocks are dark blue and the PO_4 block is pale pink.

(4) DIVALENT FORMULAS

For example, a student is required to construct the formula for calcium hydroxide. He finds the positive calcium blue circle block with two positive-ion right arms, and fits them onto two separate negative red square hydroxyl radical blocks, each with one left slotted arm giving him the formula $Ca(OH)_2$.

Mercury, iron, copper, and gold have *two* valences, making either *ous* or *ic* salts, and are therefore represented by triangles with *two* shades of blue, and two or three pointed arms. To make the formula for ferric chloride, just fit three of the negative-ion red chlorine blocks to the triangular iron block, which is colored two shades of blue, and three right arms, making the formula $FeCl_3$. To make ferrous chloride, attach two chlorine blocks to two dark blue arms of the iron block, forming $FeCl_2$.

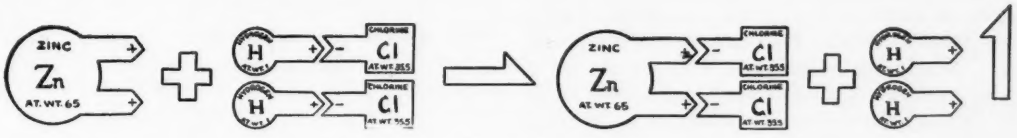

FIGURE 2

(5) POLYVALENT FORMULAS

The complicated polyvalent formulas representing several negative or positive valences are demonstrated by the rectangle blocks with both positive- and negative-ion arms, and both red and blue colors. To form sulfur dioxide, the student picks out sulfur, a rectangle-shaped block which has several valences as indicated by the six positive arms, and two negative ones colored both red and blue. Next, he fits two two-armed oxygen circles to four positive arms on the sulfur block, giving the formula SO_2. Two H (hydrogen) blocks may be fitted to two sulfur arms to form H_2S, hydrogen sulfide. (The various valences and ions are marked on these blocks.)

(6) CONSTRUCTING EQUATIONS

To work out a single replacement equation, for example, the student sets up his formula for sodium chloride by fitting an Na and a Cl block together.

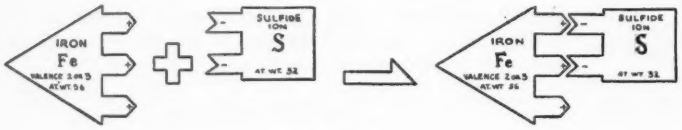

FIGURE 3

What would happen if the sodium chloride were treated with nitric acid (HNO_3)? He fits together a hydrogen circle and a nitrate (NO_3) block forming HNO_3 (nitric acid), and places a plus sign between NaCl and HNO_3 followed by an arrow sign. He next switches the Na to the other side of the arrow, fitting it to NO_3. The Cl unites with the H; thus making the two formulas, HCl and $NaNO_3$ for the new compounds formed ($HNO_3 + NaCl \rightarrow NaNO_3 + HCl$).

The student might next take his hydrochloric acid formula, HCl, and combine it with K_3PO_4, by joining three single-armed potassium blocks to it. He lines up three HCl blocks with the K_3PO_4 with a plus sign in between, but notes there are three negative arms on the PO_4 to be satisfied with three potassium blocks. Three sets of blocks making HCl formulas are obviously required. If he carries the blocks over to the other side of the $\rightarrow$ sign, the three H's unite with the three arms of the PO_4. The three K's unite with the three Cl's completing the equation $3HCl + K_3PO_4 \rightarrow 3KCl + H_3PO_4$. A double set of blocks may be used to keep both sides of the equation before the student.

Five types of typical reactions are easily demonstrated with the blocks by fitting them together to form formulas and equations: (*a*) *Direct combination*, $2Fe + O_2 \rightarrow 2FeO$; (*b*) *Simple decomposition*, $2HgO \rightarrow 2Hg + O_2(HgO_2)$; (*c*) *Single replacement*, $Zn + 2HCl \rightarrow ZnCl_2 + H_2$; (*d*) *Reactions which go to an end*, $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$; (*e*) *Reversible reaction*, $2Fe + 3H_2O \rightleftharpoons Fe_2O_3 + 3H_2$.

When the student progresses in chemistry and prepares for his examination or quizzes, he should possess the information and ability to complete equations and solve problems. The blocks coördinate admirably with standard high-school chemistry texts, and may serve to amplify, make visual, and explain the problems incident to understanding chemical reactions and equations.

SUMMARY

In the classroom and laboratory, the teacher may illustrate many difficult chemical concepts with the large-sized demonstration models, and the student may follow the demonstration with a set of his own. The student should manipulate the blocks systematically, thus learning the valences and ionizations of the common elements or radicals covered in the course of study. By keeping each set of blocks together according to valence, the student may learn to associate the elements with their valences, metallic or non-metallic properties, ionization, acid or basic properties, learn the commonly used atomic weights, relative stabilities of compounds formed, and so forth. With the use of the blocks, equation writing becomes easy, and the student may master the fundamental concepts of inorganic chemistry by visualization and practical construction methods.

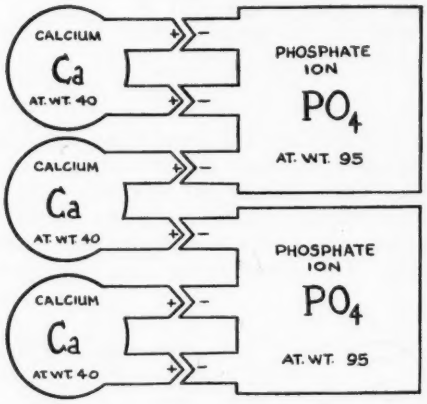

FIGURE 4

MEETING OF THE BOARD OF PUBLICATION, DIVISION OF CHEMICAL EDUCATION

At a meeting of the Board of Publication held April 8, 1940 in Cincinnati, the following action was taken.

(1) Dr. Norris W. Rakestraw was elected Editor of the JOURNAL OF CHEMICAL EDUCATION for the term August 1, 1940 to September 1, 1942.

(2) Dr. R. A. Baker was elected Chairman of the Board of Publication.

(3) A motion was passed that the High School Committee be authorized to publish "Chemistry at Work" (or some such title relating to Industrial Chemistry).

PAUL H. FALL, *Secretary*

RETENTION *in the* PHYSICAL SCIENCE SURVEY COURSE[1]

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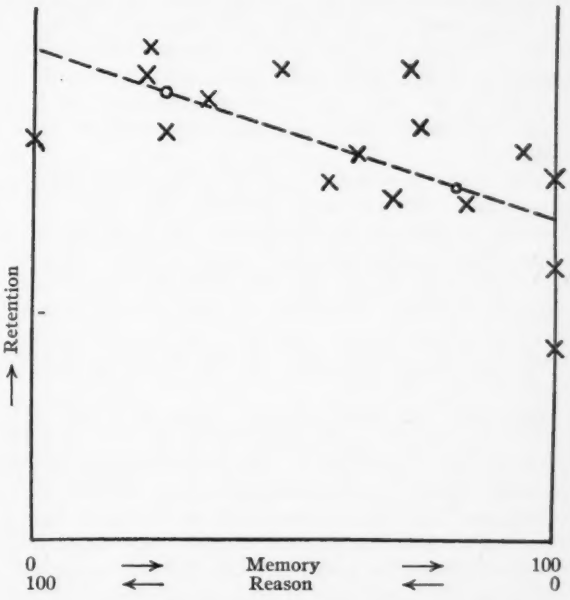
DOUBT is frequently expressed, both by students and educators, as to the permanence of the knowledge gained in a science survey course. Those whose faith is placed in the laboratory method alone feel that, since the survey students do not themselves perform experiments, their knowledge, gained from viewing demonstrations, hearing lectures, and studying books, cannot be sufficiently vivid to be permanent. The wide scope of a survey course causes many to feel that such an extensive field can be covered only superficially and that, therefore, such learning must necessarily be lost rapidly. Frequently, also, the only criterion of a student's success or failure in the survey course is a comprehensive examination, a condition which, in the eyes of many people, must encourage "cramming" at the expense of systematic day-by-day study, and "cramming" is believed to be almost valueless as a means of acquiring permanent knowledge. The experiment described in this paper was performed with the purpose of testing the accuracy of the above statements. It was hoped, also, that investigation of the retention of the different types of subject matter would yield some clues as to the selection and presentation of the material of the course.

The experiment consisted in the repetition, after one year, of the comprehensive examination in physical science given in June, 1937. A group of one hundred twelve students was available for the test; after securing their coöperation by explaining the purpose of the experiment, the examination which they had taken a year before was administered under conditions as similar as possible to the original, without any opportunity for study. The only condition which could not be reproduced was the nervous strain of taking an important examination; in the present case the students knew, of course, that the results of the examination would not appear on their college record. According to statements of individual students, the nervous strain stimulates some and hinders others, the former group being apparently somewhat more numerous. On the whole, the coöperation of the students was splendid.

It should be noted that the examination given was not designed for this experiment, but was instead one of the regular course examinations. It was entirely objective, consisting of four hundred thirty-nine items grouped into sixteen parts according to subject matter and type of question. Because of the large number of items, it was thought that relatively few of them would be remembered individually, and that therefore the "practice effect" would be small. A much larger uncertainty would have been introduced by the attempt to construct a second examination testing the same knowledge as the first, but using different wording. Unfortunately, these students had taken no inventory test to measure their knowledge when they started the course; the score of the 1937 examination represents the sum total of their knowledge up to that time, not merely that gained in the survey course. There is no way of correcting this score so as to exclude previous information. To obtain such results it would have been necessary to postpone the experiment for two years.



The ratio of the mean score in 1938 to that in 1937, a quantity which is ordinarily known as the retention and which will in this paper be called the apparent retention, was 75.6 per cent. This is a somewhat higher figure than was expected by even the more enthusiastic advocates of the survey course. In the

[1] Presented before the Division of Chemical Education at the ninety-sixth meeting of the A. C. S., Milwaukee, Wis., September 7, 1938.

literature concerning college students two groups of results are reported; one showing retentions ranging from about sixty to eighty per cent.[2] and the other showing retentions of one-half or even less.[3] Studies of retention in high school subjects usually agree more closely with the former group.[4] Retention in the survey course compares favorably with that in other college subjects, even those taught by the laboratory method. However, very few results on retention in the physical sciences on the college level have been published. In this connection it should be noted that the experimental group, as judged by the results of the 1937 examination, was slightly better than the whole class. The mean 1937 score of the whole class was 62.4 per cent., while that of the experimental group was 64.0 per cent. This was to have been expected, since it is in general the poorer student who drops out of college before completing his course.

The effect of sex is noticeable but not marked; the apparent retention of the boys was 76.9 per cent., while that of the girls was 71.4 per cent. In considering these results it should be noted that only 45.4 per cent. of the girls took subsequent courses in the physical sciences, while 62.4 per cent. of the boys continued in this field. As only twenty-seven girls were in the group, possibly these figures are not typical of large classes.

The apparent retentions of the individual students range from 28.7 per cent. to 107.6 per cent. The Pearson product-moment coefficient of correlation between the apparent retentions and the 1937 scores is 0.20, too small to indicate any significant connection between the two. This result confirms the investigations of Cederstorm and Eurich.[5] Johnson,[6] however, finds a positive correlation between these two quantities.

However, consideration shows that the term "retention" as applied to the ratio of the scores on the two examinations is misleading. The 1938 score is made up of items which were answered correctly in 1938, but which may have been either right or wrong in 1937. If an item was answered right on both examinations, it may be said to be retained, but if it was answered wrong in 1937 and right in 1938 it represents not retention, but a gain during the intervening year. This point is illustrated by the highest individual ratio found, 107.6 per cent. If this were truly retention it could not possibly be above one hundred per cent., but the ratio of the scores is above one hundred per cent. whenever the student has gained more than he lost during the interval. To distinguish between true retention, loss, and gain, the data were analyzed as shown in Table 1. There are three possible responses, right, wrong, and omitted, represented by *r*, *w*, and *o*, respectively. In comparing two examinations nine combinations are possible: *rr*, *rw*, *ro*, *wr*, *ww*, *wo*, *or*, *ow*, *oo*, where the first letter indicates the response to the 1937 examination and the second that in 1938. Every item was classified in this way (a total of 98,336 responses in all), and a table such as is shown in Table 1 was constructed for each student. The true retention is found by dividing those items listed in the column headed *rr* by the total 1937 score, the sum of the columns *rr*, *rw*, and *ro*. The loss is found by dividing columns *rw* plus *ro* (omitted items are considered incorrect in grading) by the 1937 score. The gain, on the same basis, is the ratio of the sum of the *wr* and the *or* columns to the 1937 score. The apparent retention (the ratio of the scores) is seen to be actually the sum of the true retention and the gain, though in the literature it is called simply "retention." There is a considerable difference between the true and apparent retentions; in the present case, the true retention is 59.8 per cent., while the apparent retention is, as quoted above, 75.6 per cent. The difference, amounting to 15.8 per cent. of the 1937 score, or about ten per cent. of the total number of items, is not retention but gain. The most serious consequence of using the term retention to indicate the ratio of scores is that the loss is made to appear much smaller than it actually is. For example, the loss indicated by a "retention" of 75.6 per cent. would be 24.4 per cent., whereas it actually is 40.2 per cent., since the true retention is only 59.8 per cent. Probably both the loss and gain items result largely, not from a changed conviction on the part of the student as to what he believes the correct response to be, but rather from a general haziness on the subject. If a student answers the same way on both examinations, he is apparently fairly sure of the response which he believes to be correct, but changing from one answer to another might easily be the result of uncertainty.

As many of the students had taken chemistry and physics courses during the intervening year, the effect

TABLE 1

METHOD OF ANALYSIS

One of the following tables was made for each student. Each line in the table represents one of the sixteen parts of the examination.

r = right *w* = wrong *o* = omitted

	rr	*rw*	*ro*	*wr*	*ww*	*wo*	*or*	*ow*	*oo*
1	8	6	0	0	1	0	0	0	0
2	25	13	0	1	0	0	0	0	0
3	0	3	—	—	—	—	—	—	—

and so on

An entry in the *wr* column means that the item was answered wrong in 1937 and right in 1938.

Synopses were made of these tables, classifying the students by physical science courses taken.

1937 score	= *rr* + *rw* + *ro*
1938 score	= *rr* + *wr* + *or*
True retention	= *rr* divided by 1937 score
Loss	= (*rw* + *ro*) divided by 1937 score
Gain	= (*wr* + *or*) divided by 1937 score
Apparent retention	= 1938 score divided by 1937 score
	= (*rr* + *wr* + *or*) divided by 1937 score
	= true retention + gain
True retention + loss	= 100 per cent. of 1937 score

[2] CEDERSTORM, *Pedagog. Sem.*, **38**, 516–20 (1930); EURICH, *J. Ap. Psych.*, **18**, 209–19 (1934).

[3] GREENE, *J. Educ. Research*, **24**, 262–73 (1931); JOHNSON, *J. Educ. Psych.*, **21**, 37–47 (1930).

[4] FRUTCHEY, *Ohio Educ. Research Bul.*, **16**, 34–7 (1937); TYLER, *ibid.*, **9**, 490 (1930); DOUGLASS, *Math. Teacher*, **29**, 287–88 (1936).

[5] *Loc. cit.*

[6] *Loc. cit.*

of such subsequent training had to be evaluated. The students were grouped according to their training as shown in the left-hand column in Table 2. The apparent retentions of each group in each type of subject matter are given. In using this table and the next, caution must be observed in drawing conclusions because of the small size of the groups. It will be seen that students who have taken either chemistry or physics have an apparent retention about eight per cent. higher than that of their non-scientific classmates, while those who have taken both subjects have a retention about eighteen per cent. higher. Students who have taken chemistry do better in chemistry, and students who have taken physics do better in physics, than those who have had neither subject in college. In other subjects, however, there is not much difference in the retention. Two exceptions should be noted: the students who have taken physics are better in chemistry also, and those who have taken both chemistry and

TABLE 2

APPARENT RETENTION BY SUBJECTS AND BY GROUPS

Group	*Number in group*	*1937 mean (per cent.)*	*Physics, chemistry, astronomy*	*Physics*	*Chemistry*	*Geology*	*Astronomy*	*Retention in all subjects*
No science	16	64.5	76.2	73.3	70.8	60.2	70.2	69.4
High school science only	31	58.4	73.6	74.2	74.8	55.7	77.6	70.8
College physics	9	65.8	88.2	97.2	83.8	57.8	71.8	79.1
College chemistry	46	65.6	80.3	73.7	90.4	60.6	70.1	77.3
College physics and chemistry	10	70.3	90.5	86.3	100.0	66.0	84.7	87.0
Retention of whole group	112	64.0	79.8	77.0	84.2	59.6	73.6	75.6

physics are slightly better in other subjects as well. The significance of both figures is open to serious question because of the extremely small size of the groups; the second is partially explained by the higher mean on the 1937 examination, which suggests that this group has an exceptionally high scientific ability. Another anomaly is found in the high retention in astronomy shown by those students who had taken only high-school science. The order of retention of the whole group in the various subjects should also be mentioned: chemistry, physics, astronomy, and then, very low, geology. This is partially due to the fact that many more students take chemistry subsequently than physics, while it is impossible for them to take either astronomy or geology. The low retention in geology will be discussed later.

As it seemed desirable to study the true retentions from the above point of view, Table 3 was constructed, in which the apparent retentions given in Table 2 are broken up into true retentions and gains. On examination a curious observation can be made; the true retention is seen to change as does the apparent retention —better in physics for the physics student, better in chemistry for the chemistry student, with little difference elsewhere; but the gain for all groups of students is much more nearly constant, and the variations which do occur seem to be erratic. This leads to the unexpected conclusion that further training in physical science is effective in preventing a student from changing a correct answer to an incorrect one, but much less so in causing him to change an incorrect answer to a correct one. It is true that, taken on a percentage basis, the variations in the gain appear considerably greater, but even then they are not as large as those of the true retention in most cases. This point merits further study both from the experimental point of view, to check the validity of the results of this experiment, and also, if they are proved valid, from the theoretical, to interpret its significance in analyzing the learning process.

TABLE 3

TRUE RETENTION AND GAIN BY SUBJECTS AND BY GROUPS

Upper figure represents true retention (1937 right, 1938 right). Lower figure represents gain (1937 wrong or omitted, 1938 right).

Group	*Number in group*	*1937 mean (per cent.)*	*Physics, chemistry, astronomy*	*Physics*	*Chemistry*	*Geology*	*Astronomy*	*Retention in all subjects*
			61.4	52.9	56.4	47.5	56.5	54.7
No science	16	64.5	14.8	20.4	14.4	12.7	13.7	14.7
High-school science			59.6	53.6	57.4	43.0	55.9	53.8
only	31	58.4	14.0	20.6	17.4	12.7	21.7	17.0
College			74.8	72.6	70.2	47.3	58.5	64.8
physics	9	65.8	13.4	24.6	13.6	10.5	13.3	14.3
College chem-			66.9	54.3	74.8	48.1	51.1	61.7
istry	46	65.6	13.4	19.4	15.6	12.5	19.0	15.6
College physics and chem-			79.5	65.3	82.5	54.4	64.2	70.9
istry	10	70.3	11.0	21.0	17.5	11.6	20.5	16.1
Retention of whole			66.3	56.6	68.3	47.2	55.1	59.8
group	112	64.0	13.5	20.4	15.9	12.4	18.5	15.8

One of the aims of this study was to see if any information could be derived as to the selection of subject matter for the course. With this in mind, Table 4 was constructed, arranging the various parts of the examination in decreasing order of the apparent retention. All questions are considered to be answered by the use of memory or reason or a combination of the two, and the parts of the examination may be roughly rated as to the percentage of items probably answered by memory. It should be recalled that the examination was not designed for this experiment; if it had been the questions would have been constructed with this in mind, to test as nearly as possible pure reason or pure memory. Column 3 gives such a rating; it is seen that most of the items in the upper half of the table, which

were well retained, require less memory than reason; while those in the lower half, which were poorly retained, require less reason than memory. The same information is presented in a graphical way in the figure. The wide scattering of the points indicates that the relation is only a general trend, and is in no sense accurate in detail; but that it is real can be seen from the line joining the points which represent the averages (both as to retention and memory) of points to the left and right, respectively, of the fifty per cent. memory line. The distinct slope indicates that there is a decided connection between the amount of reason involved and the retention.

The case of geology is especially interesting. The two exercises which show much the worst retention of any are in that field. One requires a knowledge of

TABLE 4

PARTS OF EXAMINATION IN ORDER OF DECREASING RETENTION

Part	*Apparent retention*	*Memory per cent.*	*Type of exercise*
3	93.2	22	True–false; judgment of validity of reasoning. Applications of physical principles
10	88.6	47	True–false; chemical principles and related facts
6	88.5	72	Selection; tell whether statement is true of sound or light or both. Wave motion; largely facts and definitions but connected by theory
7	87.9	21	Completion; principles of equilibrium
2	83.5	33	True–false, selection of related principle. Applications of astronomical, physical, and chemical principles
16	78.0	74	True–false; astronomical facts, definitions, principles
9	77.3	25	Selection; application of principles of oxidation-reduction
4	75.9	0	Completion; physics problems
11	72.9	62	True–false; geological definitions, facts, some principles
8	72.6	94	Completion; chemical definitions grouped around electron and ionization theories; facts of metallurgy
1	67.7	100	Matching; naming discoverers of laws, theories, and so forth
15	67.6	56	Selection; tell whether statement is true of nebular or planetesimal hypothesis or both
14	64.1	69	True–false; astronomical principles and definitions
5	62.9	83	True–false, completion; optics and electromagnetic theory; mostly factual, some applications of principles
13	51.1	100	Matching; placing geological events in correct eras and periods
12	36.1	100	Completion; geological terminology, recognition of diagrams

many geological terms: anticline, unconformity, stalactite, peneplain, and so forth. The other requires the placing of geological events, such as the Laramide revolution, or the advent of flowering plants, in the correct era and period. Both are almost pure memory questions. The other question in geology, Number 11, asks also for facts and definitions, but in that case they are grouped around principles. It is interesting to note here that, according to statistical student opinion, geology is the most interesting and the best understood of the four sciences dealt with.

Returning to Table 4, at the top of the column headed "type of exercise," note the prevalence of the word "principles." Where facts are found they are related to principles. Toward the bottom are the questions which involve knowledge of definitions, unrelated facts, scientific terminology. This observation serves as a guide for the selection of subject matter. It is easy to tell a student to memorize a list of properties or to learn the relative abundance of the elements in the earth's crust. But unless those facts are related in such a way that one leads to another through some theory or principle they will be forgotten; this is the kind of material which is lost. It is much more difficult to develop the theories and principles which tie the facts together, but once a principle is understood, it is not easily lost. Principles, theories, necessary nomenclature, facts from which the principles are developed or which can be deduced from them, or which illustrate them well, should form the backbone of the survey course; they will remain. In a more advanced course in science, one is justified in presenting the factual background, much of which is unrelated by theory; this is the material with which the theory-makers of the future must deal; but in a survey course, unless such material is given for the sake of showing that the small core of theories and principles which we do know is surrounded by a much larger field of fact as yet uncorrelated, it is much better to lay emphasis on the ideas rather than on the facts. Only those facts which are tied together by ideas remain; the others are lost. Tyler[7] has made a similar observation; he found that high-school students after the lapse of a year had lost very little of their ability to apply scientific principles learned in the general science course, but much more of their knowledge of scientific nomenclature and factual information.

This principle is frequently violated. The ease with which definitions of terms and detailed factual information lend themselves to the construction of objective exercises leads to an over-emphasis on this type of knowledge in modern examinations. Many of these definitions are quite unnecessary for a survey student, however important they may be for the specialist. Also, an attempt, usually unconscious, to teach the four sciences individually often results in the inclusion of much detail which cannot be adequately tied together by theory and practice in the limited time allotted. Anxiety to bring out the social significance of science or attempts to "motivate" by indicating practical uses may cause one to require knowledge of applications of scientific principles which are not themselves understood, leading in the extreme, to a degeneration of the course into a mere enumeration, with parrot-like repetition, of the more spectacular achievements of science, or to the memorizing of lists of "uses" of compounds with which the students are almost entirely unfamiliar. In physics the same thing is seen in the attempt to teach radio or television before even a moderate knowledge of the principles of electricity has been gained. It is undoubtedly important to give the student a conception of the place of science in the modern world, but that appreciation is gained perma-

[7] TYLER, *J. Higher Educ.*, 4, 203 (1933).

nently only when he understands how science has achieved those results. The teaching of a beginning course in science should be the development of understanding through the knitting together of principles, theories, and facts into one coherent whole, indicating threads leading away into the unknown but not following them. This core of understandable related material is what is remembered; unnecessary detail or material which has not been firmly fastened in place is lost. Even principles whose importance do not justify their detailed development or which cannot be adequately connected to applications and other principles are better left out.

The general results of the study seem to be:

(1) Retention is considerably higher than was expected by even the optimistic. It seems, then, that the survey course does have considerable permanent value aside from the creation of the intangible attitudes and appreciations in the development of which it is hoped and believed to be effective.

(2) The fear that the use of the comprehensive examination as the only evidence of the student's success or failure is encouraging the acquirement of purely temporary knowledge seems to be unfounded. Either it does not encourage "cramming" to the extent feared, or else knowledge acquired by "cramming" is not as easily lost as has been thought.

(3) Retention in the survey course compares favorably with that in courses in laboratory sciences given in the literature. Unfortunately, such data are very scarce in the physical sciences on the college level.

(4) Retention figures as given in the literature do not really record retention, but the sum of the true retention, and the gain in the intervening interval, which is by no means negligible. Use of such figures for retention leads to a false idea of the magnitude of the loss.

(5) The effect of further training is to increase the apparent and true retention in the subject studied, but according to the results of the present experiment, to leave the gain unchanged.

(6) The subject matter which is best retained consists of principles, theories, their applications, and related facts. That which shows the poorest retention is that which is memorized without the exercise of reason.

ACKNOWLEDGMENT

The authors wish to acknowledge the assistance of Dean William H. Conley and Miss Alice Griffin, Registrar, of Wright Junior College, who made possible the performance of the experiment; of Dr. Max Engelhart, director of the Department of Examinations of the Chicago Board of Education, in making suggestions as to the method of analysis of data; of WPA Project Number 3702, which authorized assistance in tabulating data; and especially of the students whose coöperation was so willingly given.

A PORTABLE LABORATORY *for the* MICROSCOPIST

GARRY WEINGARTEN[1]

Marshall College, Huntington, West Virginia

THE accompanying photographs illustrate a laboratory made by the author over two years ago in order that he could perform microchemical qualitative analysis at home or in the field. The "lab" was made so that it would be both portable and compact. Such a "lab" is ideal for the amateur chemist or hobbyist who is interested in micro-qualitative analysis. The arrangement and size may be changed to suit the individual requirements of the microscopist.

With the exception of the reagent block, the "lab" is of three-eighths inch plywood construction. The outside dimensions for each section are twelve and three-quarters by fifteen and one-half by three and three-quarters inches. The reagent block is made of two pieces of three-quarter-inch pine fifteen inches by six and three-quarters inches, and spaced three-quarters of an inch apart. There are seventy-six fifteen-sixteenths of an inch holes drilled in the blocks so that these holes correspond. The rest of the construction is evident from the photographs.

[1] Present address: Southern Laboratories, Huntington, West Virginia.

For the protection of the loose apparatus and reagents during transportation, a panel is inserted in each section to keep the apparatus and chemicals in place.

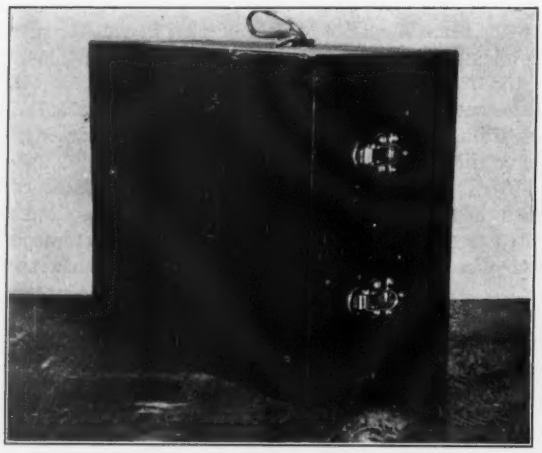


FIGURE 1.—AS THE LABORATORY APPEARS WHEN IT IS CLOSED AND READY FOR TRANSPORTATION. THE DIMENSIONS OF EACH SECTION ARE FIFTEEN INCHES BY TWELVE INCHES BY THREE INCHES. THE ENTIRE OUTFIT WEIGHS ABOUT FORTY POUNDS

A three-eighth inch clearance must be allowed for inserting the panel of each section. These panels may be used also for a test-tube rack and a work table by drilling holes for test-tubes and by painting the panels with acid-proof paint.

The reagent bottles are thirteen-sixteenths of an inch in diameter and two and seven-eighths of an inch long.

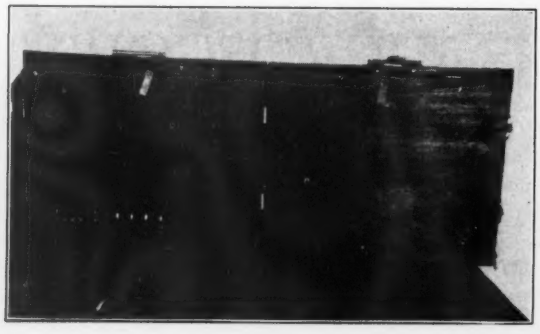


FIGURE 2.—SHOWS THE OUTFIT WHEN FIRST OPENED. NOTE THE TWO PANELS. THE HOLES IN THE LOWER LEFT-HAND CORNER OF THE LEFT HAND LEAF MAKE UP THE TEST-TUBE RACK

The two-sixteenths of an inch difference in diameter between the reagent bottle and the hole for it in the reagent block is taken up by a rolled-up filing card glued in place. This makes a snug fit and compensates for any difference in the diameters of the bottles. All labels are protected by cellophane tape.

Since the photographs were taken, the author has obtained two-ounce glass-stoppered bottles of the mushroom type for the acids. The old type (illustrated) is used for the alkalies and the other liquid reagents.

FIGURE 3.—THE OUTFIT WITH THE LEAVES DOWN

The left-hand section carries the reagents, liquid and solid. The right-hand section carries the apparatus and the knowns that are used for confirmation.

The left-hand panel has sections painted white and silver to aid in the examination of different colored precipitates on slides or watch glasses.

Any type of inorganic microchemical analysis, such as alloy, ore, and mineral, and some organic microchemical

FIGURE 4.—THIS PICTURE SHOWS THE ARRANGEMENT OF THE APPARATUS, INCLUDING GLASSWARE AND CENTRIFUGE. THE SMALL BOXES CONTAIN PIPETS, TEST-TUBES, FORCEPS, SMALL MAGNIFIERS, AND SO FORTH

analysis such as alkaloidal, textile, paper, and so forth, may be performed with this kit.

For his analytical work at home the author uses a bridge table covered with a plywood board to insure solidarity. Thus it is possible to do analytical work while seated comfortably.

Since centrifuging is an important operation for the microscopist, a centrifuge is essential. Should the regular laboratory centrifuge be too costly for the average microscopist, a satisfactory substitute may be made from an inexpensive hand drill, two centrifuge tube holders, a clamp, and several screws, nuts, and bolts. The collars for the centrifuge tube holders were cut from three-quarter-inch pine. With a little ingenuity, the operator can have a centrifuge which is both efficient and inexpensive.

A microscope lamp can be made from a tin can, a small ring-stand base, two six-inch nipples to fit the base, and two clamps. A thirty-watt clear daylight bulb is used for illumination. The can is covered inside and out with aluminum paint to increase its efficiency and appearance. Details for construction are evident from the photographs.

For heating purposes the author uses alcohol lamps made from two inkwell bottles, corks, and two small sections of an old blowpipe. Cotton twine may be used for wicks.

An important article for the microscopist to have is a fairly good-sized mirror. The author uses a mirror as a base when carrying out microchemical reactions on slides. In this way slight turbidities will not be overlooked.

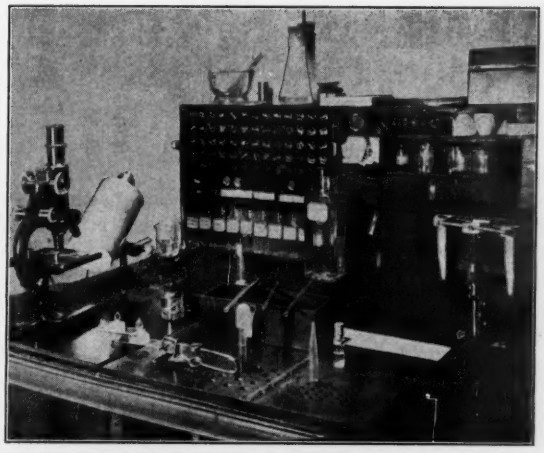


FIGURE 5.—THE LABORATORY AS IT APPEARS WHEN READY FOR USE WITH THE MICROSCOPE AND MICROSCOPE LAMP IN PLACE

The microscope lamp was made from a tin can, and the centrifuge was made from an old drill and some odds and ends. The centrifuge when taken down fits into the space in the center at the extreme right.

The necessary reagents and apparatus will depend on the use the analyst will have for his kit. The reagents and apparatus can be obtained from any supply house.

CHEMILUMINESCENCE *or* COLD LIGHT INVESTIGATIONS

LEROY D. JOHNSON

Storer College, Harper's Ferry, West Virginia

THERE appeared in the March, 1934, issue of THIS JOURNAL an article by E. H. Huntress, L. M. Stanley, and A. S. Parker on the oxidation of 3-amino phthalhydrazide or luminol as a lecture demonstration of chemiluminescence. Subsequent articles[1,2] have appeared in THIS JOURNAL referring to this phenomenon of cold light in the laboratory.

The writer has attempted an investigation on certain members of the legume family to see if there were any differences in their ability to produce cold light.

A comparative study of these legume reactions and the interesting results that have been obtained leaves a question in the mind of the writer. Could not this production of cold light be a means of partially determining structure since it is believed that this production of cold light is based on oxidation of certain ring structures in these plants? Further investigations along this line promise some interesting results.

A procedure originating in this laboratory is also outlined for the production of chemiluminescence. A modification of the Trautz-Schorigin[3,4] oxidation of a pyrogallol formalin solution by means of three per cent. hydrogen peroxide has been successfully employed for cold light demonstrations.

The writer has further discovered that an alcoholic solution of sodium peroxide can be utilized in place of sodium hypochlorite as the oxidizing agent in these light-producing experiments as outlined by Cottman.

[1] COTTMAN, J. CHEM. EDUC., **14**, 236 (1937).
[2] COTTMAN, *ibid.*, **16**, 292 (1939).
[3] TRAUTZ, *Z. Electrochem.*, **10**, 593–6 (1904).
[4] TRAUTZ AND SCHORIGIN, *Z. wiss. phot.*, **3**, 121–30 (1905–6).

The latter although producing light of lasting duration would not be recommended generally because of the danger of handling and the cost of the material.

EXPERIMENT I. LEGUMES

The reagents employed were the same as those employed by Cottman.[1]

(1) Hydrogen peroxide solution—10 cc. of three per cent. hydrogen peroxide solution is added to 90 cc. of ethyl alcohol.

(2) Alcoholic potash solution—5 g. of potassium hydroxide is dissolved in 75 cc. of water and 25 cc. of ethyl alcohol is added.

(3) Sodium hypochlorite solution—10 cc. of sodium hypochlorite is added to 90 cc. of water.

Procedure.—A few dried lima beans were placed in a 100-cc. beaker and covered wih 50 cc. of water. After the beans were split, they were boiled for fifteen minutes. Four cc. of the hot aqueous extract were poured into a graduate cylinder. To this solution was added four cc. of the hydrogen peroxide solution and four cc. of the alcoholic potash solution.

After turning out all lights and the room was darkened the investigator counted slowly to twenty-five to get the eyes adjusted.

After this count the mixture of bean solution, peroxide, and alkaline potash was added to 10 cc. of sodium hypochlorite solution.

Light, which lasted approximately four or five seconds, was immediately produced in the second graduate. There was no sign of heat.

Experiments in which dried split peas, roasted peanuts, and Kentucky Coffee Tree beans (*Gymnoclaudus Canadensis*) were used produced similar results, but the chemiluminescence varied with each legume used. The hulls of several roasted peanuts were boiled and treated similarly. The resulting solution produced cold light. Of the legumes treated the split peas produced the greatest amount of light.

Since the boiling of these legumes was approximately the same there seems to be evidence that the peas contained more oxidizable material than any of the other three legumes.

That the peanut hulls should give this reaction may not be strange since reports from the United States Department of Agriculture show that the hulls contain a great deal of nitrogen, probably bound in one of these complex structures.

EXPERIMENT II. COLD LIGHT DEMONSTRATION (ALTERNATIVE METHOD)

The method described below is a modification of the Trautz-Schorigin[4] reaction previously mentioned.

The materials employed were as follows:

Five per cent. aqueous pyrogallic acid solution
Formalin solution
Ten per cent. sodium carbonate solution
Three per cent. hydrogen peroxide

The procedure was as follows: Twenty cc. of the aqueous pyrogallol solution was added to 20 cc. of formalin solution, and this mixture added to 20 cc. of the sodium carbonate solution. After the room was darkened and the eyes accommodated, the entire mixture was added to 20 cc. of the hydrogen peroxide solution. The flask or graduate immediately gave off light. There was no evidence of heat produced and the oxidation was not as vigorous as in the Cottman procedure. Consequently not as much light was given, that is, in intensity, but the luminescence remained longer.

HIGH-SCHOOL NOTES

ELBERT C. WEAVER[1]

Bulkeley High School, Hartford, Connecticut

NEW ENGLAND ASSOCIATION OF CHEMISTRY TEACHERS SUMMER CONFERENCE PROGRAM

The New England Association of Chemistry Teachers announces that the 1940 Summer Conference will be held at the University of Maine, Orono, Maine, during August 13–16, 1940. All inquiries concerning the Conference should be addressed to the Chairman, T. C. Sargent, 834 Humphrey Street, Swampscott, Massachusetts.

PROGRAM

First Session

LAURENCE S. FOSTER, Brown University, Providence, Rhode Island, Chairman

August 13

9:00 A.M. CHARLES R. HOOVER, Wesleyan University
"High-School Chemistry as the College Sees It"

10:00 A.M. STUART R. BRINKLEY, Yale University
"The College Chemistry Course for Students with Secondary-School Preparation"

11:00 A.M. GEORGE S. FORBES, Harvard University
"Water—Some New Facts about It"

Second Session

SAMUEL E. KAMERLING, Bowdoin College, Brunswick, Maine, Chairman

2:00 P.M. HUBERT N. ALYEA, Princeton University
"Technics in Visual Education"

3:00 P.M. THOMAS H. HAZLEHURST, Lehigh University
"Construction of Molecular Models"

[1] Present address: Polytechnic High School, Long Beach, California.

4:00 P.M. ALEXANDER CALANDRA, Brooklyn College and Cooperative Test Service
Round Table Discussion—"Construction of Objective Examinations"

Third Session

ELBERT C. WEAVER, Bulkeley High School, Hartford, Connecticut, Chairman
7:30 P.M. Motion Picture Program
8:15 P.M. MARSTON T. BOGERT, Président, Union Internationale de Chimie
"The Chemist in a Chaotic World"

Fourth Session

NORRIS W. RAKESTRAW, Brown University, Providence, Rhode Island, Chairman

August 14

9:00 A.M. M. STANLEY LIVINGSTON, Massachusetts Institute of Technology
"Cyclotronics"
10:00 A.M. JOHN W. IRVINE, JR., Massachusetts Institute of Technology
"Radio-Chemistry"
11:00 A.M. FRED H. HEATH, University of Florida
"Fine Grain Development in Photography"

Fifth Session

WALTER A. LAWRANCE, Bates College, Lewiston, Maine, Chairman
2:00 P.M. AVERY A. ASHDOWN, Massachusetts Institute of Technology
"Demonstrations in Organic Chemistry"
3:00 P.M. J. PHILIP MASON, Boston University
"Polymerization"
4:00 P.M. CHARLES E. BENTON, Needham (Massachusetts) High School
Round-Table Discussion—"The General Chemistry Course for Non-College Students"

Sixth Session

THEODORE C. SARGENT, Swampscott (Massachusetts) High School, Chairman
7:30 P.M. Motion Picture Program
8:15 P.M. WALTER H. HEATH, Food and Drug Administration, U. S. Department of Agriculture
"Chemistry and New Functions of the Administration"

Seventh Session

CHARLES A. BRAUTLECHT, University of Maine, Orono, Maine, Chairman

August 15

9:00 A.M. HERBERT S. HILL, University of Maine, Orono, Maine
"Chemistry in Agricultural Education in Maine"
9:45 A.M. HARRISON C. LYSETH, Department of Education, State of Maine
"Chemistry in Maine Secondary Schools"
10:30 A.M. OLIER L. BARIL, Holy Cross College
"Soil Analysis"
11:15 A.M. PAUL D. BRAY, University of Maine
"Chemistry and Technology in the Pulp and Paper Industry"

Thursday afternoon and evening—Recreational program

Eighth Session

LESTER F. WEEKS, Colby College, Waterville, Maine, Chairman

August 16

9:00 A.M. EDWIN T. MITCHELL, Holy Cross College
"Lecture Demonstrations in General Chemistry"
10:00 A.M. HELEN S. FRENCH, Wellesley College
"Some Physical Methods of Studying Molecular Structure"
11:00 A.M. GEORGE B. HOGABOOM, Hanson, Van Winkle and Munning Company
"The Alchemist's Color of Metals"

Ninth Session

ELWIN DAMON, Keene (New Hampshire) High School, Chairman
2:00 P.M. KENNETH E. BELL, A. C. Lawrence Leather Company
"Chemistry and the Leather Industry"
3:00 P.M. HENRY A. GARDNER, National Paint Varnish and Lacquer Association
"Recently Developed Solvents and Theories of Film Formation"
4:00 P.M. ROSCOE DAKE, Phillips Academy, and STANDISH DEAKE, Milton Academy
Round Table Discussion—"The College Preparatory Chemistry Course"

Tenth Session

G. DAVIS CHASE, JR., New Britain (Connecticut) High School, Chairman
7:30 P.M. MRS. DELPHINE GREEN, United States Customs Laboratory
"Chemical Control in the Customs Service"
8:30 P.M. VIRGIL W. PETERSON, Special Agent in Charge, Federal Bureau of Investigation
"Modern Methods in Criminal Investigation"

ROSCOE E. DAVIS

Roscoe E. Davis, for three decades in the chemistry department at Lane Technical High School, first as teacher and later as head, died May 4th at the age of sixty-two years. He graduated from the University of Chicago, and spent his life in the idealistic pursuit of his calling. He had a deep interest in teaching, and was one of the most active members of the local educational group of the American Chemical Society, in the effort to extend its scope so as to aid in solving the problems of high-school chemistry teachers, and to form a bond between the objectives of high-school and college teaching. As a member of the National Committee on High-School Chemistry during the past two years he contributed to the development of the proposed high-school courses which will be further brought out this summer at the workshop of Western Reserve University. He was co-author with B. S. Hopkins, M. V. McGill, G. M. Bradbury, and H. R. Smith of a textbook of high-school chemistry entitled, "Chemistry and You" (Lyons and Carnahan, 1939). Retiring and unassuming by nature, he yet exerted a profound influence upon those who were associated with him, either as students or colleagues. His death is a real loss to American education.

NICHOLAS D. CHERONIS

CHICAGO CITY COLLEGES
CHICAGO, ILLINOIS

RECENT BOOKS

A SHORT HISTORY OF SCIENCE. *W. T. Sedgwick* and *H. W. Tyler;* revised by *H. W. Tyler* and *R. P. Bigelow*. Second Edition. The Macmillan Co., New York City, 1939. xxi + 512 pp. 61 figs. 16.5 × 25 cm. $3.75.

Teachers and students of science will welcome the appearance of this new edition of Sedgwick and Tyler's SHORT HISTORY OF SCIENCE, first published in 1917 and for many years the standard textbook of the subject. Like the earlier work, the book is the outgrowth of lectures given at the Massachusetts Institute of Technology, an institution long distinguished for the stress which it has placed upon the history of science as a part of the curriculum. The revision of the work was just completed when the death of Dr. Tyler, on February 3, 1938, left the final details of preparing the book for the press to his friend and collaborator, Dr. Bigelow.

A comparison of the first edition with the present work shows an increase in pages from four hundred seventy-four to five hundred twelve and in figures from fourteen to sixty-one. Notwithstanding this enlargement, the use of lighter paper has permitted a substantial decrease in the size of the new book. In the work of revision the text of the first edition has been so thoroughly revamped that the present volume is in many ways an entirely new book. The excellent features of the first edition, such as the inclusion of quotations from prominent authors, have, however, been retained.

In conformity with the motto from Du Bois-Reymond, "The History of Science is the real history of mankind," the new volume gives a concise and most interesting account of the cultural development of man from the dawn of history down to the beginning of the present century. The editors have very properly refrained from describing the more recent trends of science, since these are available in current literature and developments are too close for giving them a proper perspective and just evaluation.

Through a series of seventeen well-written chapters the reader follows the long story of man's development. First (Chapters I and II) is the account of primitive methods of counting, weighing, measuring land, recording time, curing sickness, and making pottery and other crude chemical products. Next (Chapters III–VII) comes the glorious period of Greek science (the early nature philosophers, the atomists, the schools of Plato and Aristotle, and the laying of the foundations of geometry, astronomy, biology, medicine, mechanics, and other sciences), a period which after a thousand years of rise and decay came to an end in the breakup of the Roman Empire. Then (Chapters VIII–IX) follows the story of the preservation of Greek science by the Arabs and of its transmission to Western Europe, of the founding of the medieval universities, of the renaissance and the awakening in medicine, astronomy, natural history, and chemistry. Next (Chapter X), with the invention of printing and discovery of America, there is a breaking with old traditions; man's intellectual horizon is immensely widened and a powerful stimulus is given to all branches of science. It is the time of Galileo, Copernicus, and Kepler. Then (Chapters XI–XIII), ushered in by Francis Bacon, comes the wonderful seventeenth century, with the towering figures of Boyle, Huygens, Leibnitz, and Newton, when the foundations of many branches of modern science are laid. Next (Chapter XIV) come the developments of the eighteenth century, when, under the leadership of Franklin, Linnaeus, Black, Priestley, Scheele, Laplace, Lavoisier, and others, the natural and physical sciences underwent a new birth. Lastly (Chapters XV–XVII) the advances and tendencies in the mathematical, physical, chemical, and biological sciences during the nineteenth century are told with brief discussions of the work of Davy, Liebig, Faraday, Bunsen, Pasteur, and others. Following these chapters are three appendices: (*A*) brief accounts of important inventions that resulted from the scientific discoveries of the eighteenth and nineteenth centuries (steam engine, spinning frame, cotton gin, explosives, illuminating gas, photography, anesthetics, India rubber, telegraph, telephone, electric lighting, food preservation, gas engines, synthetic dyes, and so forth); (*B*) a chronological list of important names, dates, and events in the history of science and civilization; and (*C*) a list of over three hundred general reference books on the history of science, with supplementary lists of biographies, source books, and journals. A twelve-page index completes the volume.

A few comments are submitted regarding certain statements that attracted the reviewer's attention. The remarks (pages 80–1) concerning Plato's views on the transmutation of the elements require modification. Timaeus, the Pythagorean speaker in Plato's dialogue of this name, states (Section 49-*c*) that earth, water, air, and fire are mutually convertible, but later (Section 54-*c*) remarks that he was mistaken in saying this about earth, for the square faces of its cubical particles do not permit of being split into the similar triangles that make up the faces of the polyhedral particles of water, air, and fire (Sections 55, 56). The particles of earth on being resolved become earth again, but the twenty-face particles of water on being resolved are split into two eight-face particles of air and one four-face particle of fire (a lucky guess of the proportions H_2O). The elimination of the unconvertible earth, or rust, of base metals (the process of *exiosis* or derusting) was therefore made the first step by the later Greek alchemists in their process of transmutation.

The statement concerning the controversial subject of ether anesthesia (page 445) also needs emendation. The employment of ether for the painless extraction of teeth and in surgery was suggested to T. G. Morton by Dr. C. T. Jackson, who in his Boston laboratory as early as 1837 used breathing of ether vapor for alleviating the pain caused by inhalation of chlorine. The question of whether Jackson or Morton deserved credit for its application to surgery was referred to the French Academy of Arts and Sciences which decided that Jackson deserved credit for the idea and Morton for the demonstration. Dr. Long's use of ether in his private practice, four years before the demonstration in the Massachusetts General Hospital, is well authenticated, but general knowledge of his discovery did not come until years later so that it played no part in the movement that led to the wide introduction of painless surgery.[1]

The remark (page 65) that Democritus wrote in verse is open to question. The Greek quotations from this philosopher in the *Fragmenta Philosophorum Graecorum* are in prose. The Greek words for yellow and black bile (page 70) should be in the nominative (chole xanthe and melaina), and the Greek word for soul in the title of Aristotle's work (page 93) should be in the genitive (Peri psyches). E. von Bergmann (page 446) is wrongly indexed under T. O. Bergman and Celsius (page 353) under Celsus. The misspelling Belle (page 467) and the erroneous date 1790 for Washington's death (page 482) are among other minor slips that should be listed in the errata.

In a work of this scope there will naturally be differences of opinion with regard to the emphasis that should be placed on particular sciences and as to what should or should not be included. Some biologists (as Professor E. G. Conklin) will no doubt criticize the statement (page 429) that the cell theory was first conceived by Schwann and Schleiden; many chemists will consider the failure to mention the discovery of the rare gases by Ramsay a serious omission; while the admirers of Francis Bacon may perhaps lament that his influence in stimulating the movement that led to founding the Royal Society and various academies of science was not sufficiently stressed. These possible objections, however, are of minor consideration in view of

[1] See the reviewer's account of the ether controversy in his article, "Emerson and chemistry," J. CHEM. EDUC., **5**, 275–6 (1928).

the main purpose of the book which, as indicated in the preface, has been to trace briefly the history of the foundations on which advances in science are based; to correlate the steps of progress with the spirit of the time; to increase the emphasis on the evolution of scientific methods, and thus to give an infusion of continuity in the history of science. In the opinion of the reviewer this purpose has been admirably achieved, and the present work is warmly recommended as an introductory textbook of the history of science both to the student and to the general reader.

The typography and binding of the new volume are excellent. Particularly pleasing are the design, on the outside of the book, of a Tyrolean quadrant and, on the inside of the covers, the reproduction of a curious old sketch of 1594 illustrating various uses of the geometrical quadrant. The illustrations, which were either drawn or arranged by Mrs. Elizabeth Tyler Wolcott, add greatly to the enjoyment of the book.

C. A. BROWNE

BUREAU OF AGRICULTURAL CHEMISTRY AND ENGINEERING
UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

THE STOREHOUSE OF CIVILIZATION. *C. C. Furnas*, Associate Professor of Chemical Engineering, Yale University. Bureau of Publications, Teachers College, Columbia University, New York City, 1939. xx + 562 pp. 15 × 23 cm. $3.25.

According to the editor's preface, this volume ". . . . has been prepared to help teachers and others understand how we can bring about a more effective production and distribution of goods and services." Mr. Powers, the editor, goes on to say that these volumes, of which this is one, " . . . . have been prepared . . . . especially for curriculum workers and for teachers of science and other subjects in an effort to help them to serve with increasingly greater effectiveness the younger people whom society places in their charge."

This book would serve any teacher as an invaluable source book and guide. The author has provided an overview of the informational facts and statistics associated with this whole topic and in addition has let himself pass judgment on problems that are frequently debated. His philosophies on trends and possible outcomes are as entertaining as they are informational. This fact in itself should make this book fascinating to the layman as well as to the scientist and teacher. Moreover, this analytic type of presentation catches the reader just at a moment when he is cognizant of consumer education and analysis of propaganda. This may cause him to be skeptical at times of the author's concepts and challenges but surely none the less appreciative.

A list of the unit or chapter headings will give to a prospective reader an idea as to the organization of the subject. They are: I. The Raw Materials; II. The Formation of Mineral Deposits; III. Discovering, Recovering, and Concentrating the Minerals; IV. Winning the Metals; V. Properties of Metals; VI. Use and Misuse of Metals; VII. The Non-Metallic Minerals; VIII. The Energy Supply; IX. The Chemical Age; and X. Social Impacts and Implications as Viewed by an Engineer. This book is not a textbook in the sense that it is merely a manual of instructions. While it surveys and, in many instances, explains various principles relating to metals, non-metals, energy, and chemical products, it goes much further than that.

Mr. Furnas has brought together a wealth of informational tables from varied sources. Many of these charts and graphs have been constructed for this book from data supplied elsewhere. There are a few instances in which the data could become increasingly meaningful to even the author's treatment if two or more charts were to be combined. For example, the "relative consumption . . . ." of an element by different agencies during a series of years is one factor, but accompanying it with the absolute consumption might be even more illustrative. The book has been well supplied with charts, tables, and figures all of which allow the reader to go beyond the expressed judgments of the author. Moreover, the volume is well indexed, the table of contents is sufficiently detailed, and there are numerous references to the literature and to the sources of statistical information.

Mr. Furnas possesses a gifted technic for briefly describing a present-day theory and showing the significance of the ideas which preceded it. The brevity and cautious generalizations that he concedes would make many of his paragraphs and even pages a valuable addition to almost any elementary chemistry and physics textbook. He demonstrates the lack of validity and consistency on the part of definitions but remembers that in teaching, a tangible, concrete concept is far more valuable than any highly abstract and technically precise definition even though it be slightly less accurate.

This book is interestingly organized in that the author alternately assumes the rôle of a historian, a social scientist, a technologist, and a natural scientist. Mr. Furnas describes the evolution of steam power from the time that Egyptian priests made use of it in operating the temple doors. He discusses the possible advantages a nation might realize by not possessing an adequate mineral supply. His explanations of scientific principles vary considerably, ranging from simple concepts involving the difference between compounds and alloys to examples and discussions of entropy.

This reviewer believes that everyone who reads this book, whether it be a layman, a pure scientist, a technologist, or teacher of any subject, will find it interesting and enlightening. Prospective authors of science textbooks could read this book advantageously and take many ideas away with them. The author has written the book in a style that is easy to read and understand. The editor most certainly has a book for the series that fulfils each of the expressed aims. The publishers have contributed their aid in the choice of fairly large print and placing it upon a paper that is restful to the eyes.

SHAILER A. PETERSON

UNIVERSITY HIGH SCHOOL
UNIVERSITY OF MINNESOTA
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YOUNG CHEMISTS AND GREAT DISCOVERIES. *James Kendall*, M.A., D.Sc., F.R.S., Professor of Chemistry in the University of Edinburgh, General Secretary of the Royal Society of Edinburgh. D. Appleton-Century Company, Inc., New York City and London, 1939. xvi + 272 pages. 12.5 × 19 cm. Illustrated. $2.50.

Here is another title to be added to the list—and the list is still a short one—of first-rate books on popular science for boys and girls, books for Christmas and for prizes in high-school or college chemistry contests. Parents will like to read the book, and teachers will find that it makes difficult matters interesting and easily understood. This "Book of the Royal Institution Christmas Lectures 1938–9" meets the high standard set by Faraday who gave in 1826 the first series of these lectures "adapted to a juvenile auditory" and in the course of the years gave eighteen other series thereafter. It should become, like Faraday's "Chemical History of a Candle" and Tyndall's "Fragments of Science," one of the enduring classics of science popularization.

Professor Kendall tells about the life, the struggles, the personality, and the discoveries of young chemists, and he tells what the same chemists did when they were no longer young. Some were of the "romantic type" who made brilliant contributions while they were young and none in their later years; others were of the "classic type" and continuously productive throughout their lives. The book is well illustrated and contains portraits, some of them new, of distinguished chemists when they were young. It is pervaded by humor. The lectures were accompanied by experiments (described in footnotes) in some of which the actual apparatus of Davy and Faraday was used. In others a stooge was employed. "The effect of partial intoxication through inhalation of a mixture of nitrous oxide and oxygen was exhibited by two assistants. The characteristic effects of thickness of speech and lack of muscular control were obtained, and the victim, Mr. Gibbons, amused the audience by uttering on re-

covery the identical words employed by Davy" (*i. e.*, "Nothing exists but thoughts! The universe is composed of impressions, ideas, pleasures, and pains!"). . . . . "Here, in the lecture, Mr. Gibbons again inhaled a mixture of nitrous oxide and oxygen from an 'analgesic apparatus' until he was insensitive to pain. He was pinched vigorously, and pins were stuck into him, without protest. A short film showing the modern technique of a minor operation on a smiling child was also shown." The second lecture ended by a reading from one of the lectures of Faraday's most famous Children's Series. "At this point the lecturer. . . . retired from the theatre for a few minutes. In his absence, the lecture table was arranged with an elaborate display of candles of all shapes and sizes. While this was being done, pictures of Faraday were thrown on the lantern screen. The lecturer then returned, made up with white wig and side-whiskers to resemble Michael Faraday, and wearing a Victorian frock-coat and stock. In this guise he recited the remainder of the lecture in Faraday's own words." And he showed Faraday's own experiments in illustration. The last experiment of the series was one in which the lecturer and two of the auditors, Jean Kendall and John Green, passed their hands to and fro through a stream of white hot lead.

The six chapters are as follows: I. Humphry Davy; II. Michael Faraday; III. Some Young Organic Chemists (Perkin, Couper, Kekulé); IV. The Chemistry of Space and of Solutions (Pasteur, Le Bel, Van't Hoff, Arrhenius); V. Elements—Old and New (Newlands, Mendeléev, Moseley, Curie); and VI. Some Young American Chemists (Woodhouse, Hare, Hall, Langmuir).

The book is enjoyable reading, and it makes one wish that he might have heard the lectures.

TENNEY L. DAVIS

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FUNDAMENTALS OF CHEMISTRY AND APPLICATIONS. *Charlotte A. Francis*, A.M., and *Edna C. Morse*, R.N., A.M., Instructors in Chemistry, Teachers College, Columbia University. The Macmillan Company, New York City, 1939. ix + 542 pp. 111 figs. 14 × 21.5 cm. $3.00 net.

The authors have written a book for use in connection with a service course designed for students in the applied sciences and arts such as physiology, cookery and nutrition, bacteriology, materia medica, and nursing practice. They have had in mind particularly the schools of nursing and some schools of home economics, the curricula of which call for but a half-year of chemistry, or, at most, one year. Somewhat more than one-half of the book (two hundred ninety-four pages) is devoted to the presentation of the fundamentals of chemistry, while the remainder pertains to organic and physiological chemistry.

The method of presentation of the fundamentals of chemistry differs somewhat from the usual style of elementary textbooks. Oxygen is the only element discussed in detail, while water is the only compound similarly presented.

Among the topics discussed are the following: substances and some of their properties; physical and chemical changes; compounds, elements and some of their properties; oxygen; catalysts; combustion; chemical energy and methods for measuring it; atoms, molecules, atomic weights, molecular weights; symbols, formulas, and the use of the chemical equation; radicals; valence; the structure of the atom and radioactive elements; water, acids, bases, and salts, and their reactions; solutions, true and colloidal, emulsions; electrolytes, ionization, pH; oxidation and reduction.

Since the material just listed is to serve as the foundation for work in organic and physiological chemistry, the choice of subject matter seems rather limited. Although the first few pages are somewhat reminiscent of SMITH'S COLLEGE CHEMISTRY, one soon ponders over the vast amount of space devoted to "substances." In contrast "elements" and "compounds" do not make their appearance till pages thirty-two and twenty-nine, respectively, and the former term is never actually defined. Just why the authors find it necessary to discuss "oxygen, the substance" as well as "oxygen, the element" is not clear (Chapter IV), nor is it apparent why "substances" are discussed in connection with chemical reactions (Chapter IX) while the more impotant terms "molecule" and "atom" are never defined, although introduced in this chapter.

A rather common fault throughout this entire section of the book is the use of illustrations and undefined terms with which the student is probably not familiar. Before any information is presented concerning elements, compounds, molecules, or atoms, four common types of chemical reactions are listed with examples characteristic of each (Chapter II). In Chapter III, metals and non-metals are defined in terms of acids and bases, which are defined later in the same chapter in terms of metals and non-metals.

Chapter V, "Catalysts," should be particularly interesting to the advanced student because of the vast number of catalytically controlled reactions listed therein. However, a beginner can scarcely be expected to be familiar with the enzymes, maltase, lactase, sucrase, zymase, amylase, ptyalin, steapsin, pepsin, trypsin, erepsin, and rennin or with their substrates and the products of their reaction.

In Chapter IX, reactions between hydrogen and chlorine, zinc and hydrogen chloride, and phosphorus and oxygen are used as examples of molecular combinations. However, since oxygen alone has been discussed, the illustrations seem pointless. In the same chapter, the Avogadro number is introduced without name, comment, or explanation and thereafter assumed to be well understood by the reader.

A rather formidable list containing the names and formulas of twenty inorganic and five organic acids, five inorganic bases, three alcohols, and nineteen salts as well as a scheme for naming oxygen acids is presented in Chapter XI. These same compounds are again discussed in the following chapters dealing with valence and atomic structure.

The discussion of the physical properties of water (Chapter XIV) and their practical applications is one of the best sections in the entire book. Less clear, however, is the discussion of the chemical properties of water. Colloidal and true solutions are presented in an interesting fashion, especially with respect to biological application.

The latter half of the volume follows the usual scheme of an abridged textbook of organic chemistry and includes a brief discussion of carbohydrates, fats, proteins, digestion, absorption, and metabolism. This section should be very useful to students with an adequate foundation in chemistry who wish to make a survey of the field of organic and physiological chemistry. However, it is not clear just how a student trained only in the chemistry of oxygen and water can really understand even the simple reactions of halogens or hydrogen with the various types of hydrocarbons. The extensive use of structural formulas, particularly for such substances as the saccharides, sterols, lecithins, peptids, and the various types of cyclic compounds, is of doubtful value.

HELEN L. WIKOFF

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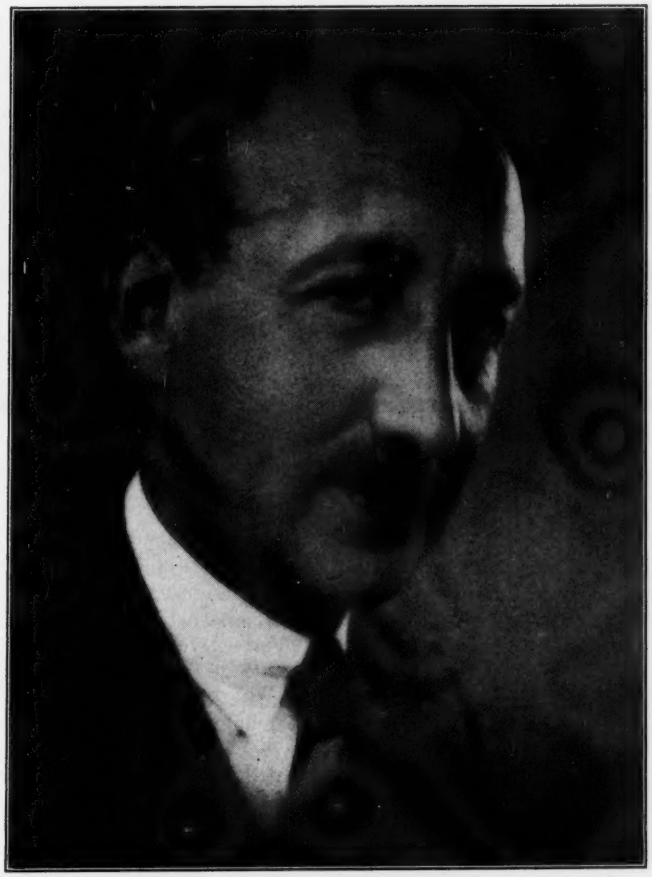
ALUMINUM. *D. B. Hobbs*. The Bruce Publishing Company, Milwaukee, Wisconsin, 1938. viii + 295 pp. 15 × 23 cm. $3.00.

This handsomely illustrated book is not primarily a chemical treatise. It does, however, contain a wealth of material on the history, metallurgy, fabrication, and uses of aluminum that many teachers of general chemistry will find invaluable.

An unusual feature of the book and one that should greatly enhance its value to high-school libraries, as well as to amateur craftsmen in general, is the series of twenty-five handicraft projects of varying difficulty described in Part II. The articles for the construction of which directions are given are all useful, and the general level of taste and artistry in design is exceptionally high for a collection of projects of this kind.

OTTO REINMUTH

THE UNIVERSITY OF CHICAGO
CHICAGO, ILLINOIS



GEORGE DE HEVESY (1885–)

Since chemistry came of age the search for new elements has been directed by reason rather than left to haphazard groping. A beautiful example is the discovery of element 72, hafnium. Application of the Bohr quantum theory of atomic structure indicated that this element must be quadrivalent, that it is not a rare earth element, that it would not be found in Marignac's ytterbium, but rather in the minerals of zirconium, a chemical relative of 72. These predictions were verified; the search was brought to a successful conclusion in 1923 in the Institute for Theoretical Physics in the city of Copenhagen, whose Latin name was Hafnia. The credit for this chemical *tour de force* belongs primarily to George de Hevesy, who was ably assisted by Dirk Coster of Groningen, Holland.

George de (von) Hevesy was born at Budapest on August 1, 1885. His training in various countries culminated in a doctorate at Freiburg in 1908. He has served as assistant, lecturer or professor at the University of Budapest, the Radium Institute at Vienna, University of Freiburg, Technical High School at Zurich, University of Manchester, Cornell. He is now on the staff of Bohr's Institute at the University of Copenhagen.

His early interests lay primarily in the reactions of fused electrolytes; later he devoted himself to the chemistry and electrochemistry of radioactive bodies. In collaboration with Fritz Paneth he introduced the method of radioactive (isotopic) indicators and applied it to various problems of analytical, inorganic, and physical chemistry. The scope of this technic has been immensely widened by the discovery of artificial radioactivity and the consequent possibility of producing radioactive isotopes of most of the elements.

In collaboration with J. N. Brønsted he made a partial separation of the isotopes of mercury and other elements. He discovered that samarium is naturally radioactive, emitting α-rays. In his extensive studies of the induced radioactivity of numerous elements he has found interesting facts; for instance, dysprosium bombarded with slow neutrons exhibits activity greater than any other element.

The occurrence of hafnium in all zirconium minerals aroused his interest in geochemistry, particularly the terrestrial and cosmic distribution of the elements. An important outgrowth of these investigations was the introduction of quantitative analysis by means of X-ray spectroscopy, a valuable advance over the earlier qualitative technic of Moseley, Hadding, Holdschmidt, and Thomassen.

(*Contributed by Ralph E. Oesper, University of Cincinnati*)

EDITOR'S OUTLOOK

MORE LESSONS. Shocked into a more realistic understanding of the genesis of war, and of the nature of modern warfare, we have hastily embarked upon an expensive program of rapid material rearmament. At last we see that the pure hearts and the unlimited intestinal fortitude we have always claimed are insufficient defenses against fire and steel. This much is good, but let us not in our concentration upon an immediate necessity abandon all consciousness of equally important fundamentals.

In our spare hours and holidays from material rearmament let us get in a few licks at moral and psychological rearmament. No chess player ever administered a crushing defeat to an opponent. Chess games are lost, not won. Given military opponents of anything like equal man-power and material resources, the same thing is true of wars.

In so far as this generalization applies to purely military operations, we must leave matters to the military experts. However, not all wars are lost on the battlefields.

This warning is not directed against fifth columns, Trojan horses, borers-from-within, and other such melodramatic menaces, real though they may be, but against a more insidious and far more nearly pandemic weakness that too few of us seem to have recognized.

For ten years, at least, this nation has been divided into three large (though, thank God, not all-inclusive) groups. Some of us have been desperately concerned with hanging on to what we, personally and nationally, have. Some of us have been conniving with grim determination to share what others have. A few have spent their time in egging on the former mutually suspicious groups, and in dexterously picking pockets as opportunity offered. Entirely too few of us have had the vision to see, and the courage and faith to believe, that this nation has a potential future greater and brighter than any fabulous golden age of her past.

The threat of war may unite us in a common purpose. Let us hope so. But unless we can, out of this unity of purpose, achieve some sort of positive national ideal, some compelling objective for the future, we shall not profit by peace if war is averted. Indeed, it is unlikely that we shall indefinitely postpone war or escape losing it if it comes.

N. N. ZININ, *an* EARLY RUSSIAN CHEMIST[1]

HENRY M. LEICESTER

College of Physicians and Surgeons, San Francisco, California

THE founder of the modern school of organic chemistry in Russia was Nikolaĭ Nikolaevich Zinin,[2] who not only pointed the way to modern thinking and modern experimental methods in a country which until his time had given almost no thought to the advances in chemistry which were then arousing the scientific world of western Europe, but who also trained a whole school of young chemists whose names became outstanding in the latter half of the nineteenth century.

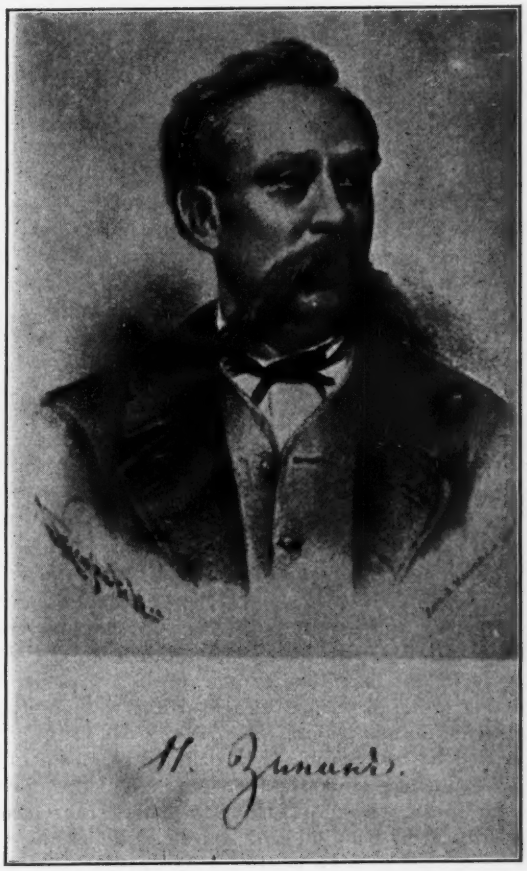
Zinin was born in Shusha, in the Caucasus mountains near the Persian border, on August 13, 1812, old style. Both his parents died within a few days of his birth, and the elder sister who took charge of him survived them by only a short time. The child was therefore sent to an uncle in the city of Saratov, and it was there that he received his elementary education.

Even in his gymnasium days he gave evidence of the powerful memory and the versatile mind which distinguished him in his later life. Whatever subject he took up he strove to master, and he usually succeeded in doing so. He first devoted himself to Latin, in which he quickly outshone his fellow students. He then became interested in botany, and spent many days in collecting specimens, and as many nights in arranging them. His physical strength and endurance were great, but the statement of his student, Butlerov, that he could jump over hedges three arshins high is open to doubt, since an arshin is two and a third feet in length.

Zinin originally planned to enter the Engineering School in St. Petersburg, but the sudden death of his uncle left him without the funds to carry out this plan, and instead he entered the University of Kazan in 1830. Although this institution had been founded only about twenty-five years earlier, it had already developed an excellent faculty. Zinin began his work in the mathematical division, where the outstanding professor was Lobachevskiĭ, the founder of non-Euclidean geometry.

During the three years of his course at Kazan, Zinin twice won a gold medal for his unusual ability, and as soon as he obtained the Candidate degree, he was appointed assistant to the professor of physics. Six months later he was made lecturer in analytical mechanics, and after another year he was given the chair of hydrostatics and hydrodynamics.

Although he seemed destined for a career in mathematics, a field in which he always retained a great interest, Zinin had for some time been developing an interest in chemistry, and a short time before he obtained his Master's degree in the physico-mathematical division



N. N. ZININ

of the University, he was transferred to the chair of chemistry. Such sudden shifts were by no means uncommon in the loosely organized universities of the time, but probably few men who made them became as

[1] Presented before the Division of the History of Chemistry at the ninety-eighth meeting of the A. C. S., Boston, Massachusetts, September 12, 1939.

[2] BORODIN AND BUTLEROV, "Nikolaĭ Nikolaevich Zinin," *J. Russ. Phys. Chem. Soc.*, **12**, 215–52 (1880); *Ber.*, **14**, 2087 (1881).

eminent in their new posts as did Zinin. From the time of this appointment he was always first and foremost a chemist.

In 1837 Zinin was awarded one of the recently established traveling fellowships which took him abroad for the first time. At this period Russian science was widely separated from the rest of Europe, and Zinin became one of the few Russian scientists who actually saw what was being done in the West. The importance of this journey, both for himself and for the future development of chemistry in Russia, cannot be overemphasized.

He visited chemical laboratories in Germany, Switzerland, France, and England, and also devoted much attention to the current developments in medicine. A group of young Russians was then studying medicine

ALEXANDER BORODIN

in Berlin, and Zinin attended lectures in physiology, microscopy, and botany with them, at the same time that he worked with Mitscherlich and Rose in chemistry. It was here that he gained the knowledge of another group of sciences to add to the wide interests which he always maintained.

When he left Berlin, Zinin planned to pay a brief visit to Liebig's laboratory at Giessen, and then go on to the south of France. He even made arrangements for a friend to meet him in France. However, as soon as he reached Giessen where Liebig was then carrying on several of his most famous researches, the young Russian realized the wonderful opportunity which lay open to him, and he canceled his southern trip. He remained at Giessen for more than a year, and absorbed the full spirit of scientific research. The actual course of his future work was also largely determined at this time, for he began work on benzoyl compounds, and with few exceptions, he continued to study these substances until his death.

He returned to Russia in 1840 and presented the results of his work at Giessen as a thesis in the University of St. Petersburg. For this thesis, "Compounds of Benzoyl and the Discovery of New Substances Belonging to the Benzoyl Family," he was awarded the degree of Doctor of Natural Science.

In the spring of 1841, Zinin returned to Kazan. During his absence, the chair of chemistry had been given to Karl Karlovich Klaus, the noted worker on platinum compounds and the discoverer of ruthenium. Therefore, Zinin was appointed Extraordinary Professor of Technology. Although he carried out the duties of this position in a striking manner, his real interest remained with organic chemistry, and he continued to work in that field. Almost at once his studies led him to his most famous discovery.

He undertook the systematic study of the action of hydrogen sulfide on various types of organic compounds. Among the first substances he used were the aromatic nitro compounds. When he treated nitronaphthalene and nitrobenzene with ammonium sulfide, he obtained two compounds which he called naphthylidam and benzidam. He gave a careful and exact description of these substances, but he did not recognize their true nature. However, when he sent his paper describing them to the *Annalen*, the German chemist, Fritsche, who read the manuscript, at once realized that Zinin had prepared aniline. When the paper was published, Fritsche added a note at the end which pointed out this fact. Thus, Zinin had for the first time synthesized this enormously important compound and shown the way for a general method of synthesis of the aromatic amines. Of this work Hoffmann said thirty-eight years later, "If Zinin had done nothing more than to convert nitrobenzene into aniline, even then his name should be inscribed in golden letters in the history of chemistry."

Zinin continued the study, and showed the general nature of the reaction by the preparation of a number of other amines. He continued to use his own nomenclature in all his papers on the subject, speaking of semi-benzidam and benzaminic acid, which we now call phenylene diamine and aminobenzoin. The work was a logical and connected whole, and showed well his outstanding ability in research. The remaining years of his stay in Kazan were occupied with the extension of his studies of these compounds into the field of azo- and azoxy-compounds, which he examined in great detail. He also prepared a number of derivatives of naphthalene.

In his theoretical ideas, Zinin was a strong supporter of the ideas of Liebig. In this field he often ran counter to the opinions of his colleague, Klaus, who remained faithful to the dualistic doctrine of Berzelius. However, Zinin always kept abreast of the latest theoretical developments, and with his advanced outlook he was in a position to guide his students in the most fruitful way.

His influence among the students grew steadily, and though he did not teach chemistry directly, he was quickly surrounded by an eager circle of chemical stu-

dents. The most famous of these, Butlerov, gives this description of him in about 1846, "He was of medium height, broad shouldered and broad chested, with a spiritual face, a lively and penetrating glance, longish black hair combed back from his forehead in front and somewhat to the right. He usually spoke standing, and from first to last, held his hearers under the spell of his talk."

His advice and council were not confined to the chemistry students. His wide interests and experience enabled him to help those who were preparing dissertations in anatomy or entomology, and they found in him both aid and inspiration.

In the laboratory, Zinin encouraged his students to work individually, and he maintained a friendly attitude at all times. Butlerov tells us, "Sometimes, when he deserved it, a student received a half-jesting scolding, accompanied by a blow. No one was offended, since he was fully entitled to answer the professor in the same way, but those attempting such an answer were few, because the attempt usually led to regret. Zinin possessed great muscular strength, and in such cases, he squeezed his opponent as if in a press. All this was accompanied with a laugh on both sides and by the bystanders." The laugh on the part of the student may sometimes have been a little forced.

Combustions at that period were events which required much labor, both in preparation and performance. Zinin usually set aside certain days for running these. In the morning the coal furnace would be prepared by the laboratory assistant, and in the afternoon, with his coat removed and his face reddened by the heat, Zinin would sit beside the furnace, carefully adding pieces of coal at the proper points, and at the same time discussing the latest problems with a group of students which always surrounded him at such times. Many of his most valuable and inspiring suggestions were given under these conditions.

In 1845 Zinin married an elderly widow with a family of grown sons. Butlerov says that this was "a union of friendship and convenience; the widow was supported by a husband, and Zinin had a housekeeper who cared for his home and allowed him to devote himself more fully and carefully to his scientific activities." A year or two later, however, this first wife died.

In 1847, Zinin was called to the chair of chemistry in the Medico-Surgical Academy of St. Petersburg. This break in his routine also caused a break in his scientific studies, and it was several years before he again began to publish at his previous rate. Shortly after his arrival at the capital, Zinin again married, and by this second marriage he had two daughters and two sons, one of whom later became professor of mathematics at the University or Warsaw.

It was not long after reaching St. Petersburg that Zinin again became the center of a group of enthusiastic students. His wide interests were given full play in his new surroundings, and his earlier attention to medicine enabled him to appreciate and assist in much of the work which was going on in the Medico-Surgical Institute. In his lectures to the medical students he stressed the scientific viewpoint as the prime mover in all medical progress. He believed that all physicians should work for a time in one of the basic sciences. While "anatomy gave an understanding only of the structure of the organism, physics and chemistry gave the key to the working of all the complexes, to the infinite number of physiological and pathological changes which were carried on in it." With these ideas in mind, he gave his courses in inorganic and organic chemistry as fully as if he had been teaching in the physico-chemical division of the university.

Shortly after he assumed his new duties, Zinin learned of the theories of Gerhardt and Laurent, and he quickly recognized the revolution in chemical thought which resulted from them. He became the first chemist in Russia to adopt them, and he did much to spread these important conceptions among his colleagues. In particular, he inspired Butlerov to throw aside the old ideas which Klaus had taught the brilliant young chemist, and thus to begin the career which was so important for all chemistry.

During his time in St. Petersburg, Zinin was kept busy on a large number of government tasks, outside the scope of his normal duties. However, he possessed tremendous energy and vitality, and through all his other activities he pursued his studies of the benzoin compounds. The laboratory of the Academy was very primitive, and there were almost no funds for its support. Nevertheless, there was no lack of students anxious to work with the popular professor, and Zinin devoted much of his time to them. The best known of this later group was the famous chemist and musician, Borodin.

Until new laboratories were built in 1867, however, Zinin did his own work in his private laboratory at home. This room was filled to overflowing with apparatus, books, chemicals and equipment, and no one but Zinin was allowed to touch anything. In his personal living quarters the same state prevailed. Borodin explains that when Zinin moved into his new house, he did not have time to arrange his effects, and before he could do so, he learned where everything was. After that, he considered the effort of learning new positions for his belongings to be useless, and matters were left as they had been. His remarkable memory was guide enough. Thus, in the words of Borodin, "I once happened to see this occur. An argument came up with a physiologist. Zinin, who understood physiology well, cited by heart the support for his statement and then, recalling under which chair lay the paper he desired, he at once went to it, without hesitation took from a dusty pile a book, opened and read it to show he was right, and then returned the book to its former place."

In his private life, Zinin was almost ascetic. He never smoked or drank, and, if possible, he avoided others who were smoking. He controlled his diet very rigidly, and often ate very little.

In 1867 Zinin was made Director of the Laboratory

at the Academy, and in 1868 he was elected president of the Russian Physico-Chemical Society. He held this position for the next ten years. In 1874 he retired from the Medico-Surgical Academy and devoted himself to work in the St. Petersburg Academy of Sciences, of which he was an active member.

In 1860 the Customs House had seized a large quantity of bitter almond oil which had been falsely declared. This was turned over to Zinin, and from that time on he worked largely on various benzoyl compounds. He prepared and studied a large number of such substances, thus continuing the work he had begun with Liebig. He also worked at various times on allyl compounds, which he called propenyl derivatives, on substituted ureas, mustard oils, and the azoxy compounds previously mentioned. In all his papers, his style was notable for its clearness and for the logical deductions drawn from the experiments which he described. His data were remarkably exact, and he made it a point to study all reactions in as quantitative a manner as possible.

Zinin continued his active chemical work until the autumn of 1878. At this time he became ill, and was forced to leave the Laboratory. For several months he continued to hope that he would be able to return to his studies, but he gradually grew worse, and on February 6, 1880, he died.

Zinin may justly be credited with founding the modern science of chemistry in Russia, and showing the ability of Russian chemists to the outside world. The organic chemist owes him a particular debt for the influence which he had on the development of Butlerov and the latter's contributions to the theory of chemical structure.

ARE WE TEACHING OUR STUDENTS *to* DISTINGUISH BETWEEN FACT *and* THEORY?

THEODORE A. ASHFORD AND WILLIAM M. SHANNER

The University of Chicago, Chicago, Illinois

THERE is wide agreement among science teachers that one of the most important objectives of science instruction is the teaching of scientific thinking (*1*, *2*, *3*, *4*, *5*). However, there is no uniformity in teaching methods for the attainment of this important objective. In fact, in most courses, no special provision is made to teach the scientific method as such (*6*, *7*, *8*, *9*, *10*, *11*). The average instructor probably expects that the student by dealing with science material will somehow develop the ability to think scientifically. The extent to which students develop ability in scientific thinking is at present a matter of opinion. Thus far, but few attempts have been made to evaluate by means of reliable tests the extent to which this objective is being attained (*12*, *13*, *14*).

The absence of uniformity in teaching scientific thinking, the paucity of studies on the outcome of such teaching, and the lack of conclusiveness of the results of the available studies may be explained, in part, by the fact that there is no general agreement as to the meaning of terms. "Scientific thinking" or "the scientific method" has not been clearly defined. Likewise there is no agreement on the meaning of terms such as fact, evidence, proof, theory, hypothesis, assumption, deduction, and so forth. Whether it is possible to give precise meaning to these elusive terms, is a moot question. It might be that there is no *one* scientific method —that for each field of investigation special methods must be devised—and that the terms mentioned have different meanings in different situations. Whatever the ultimate nature of "the scientific method" may be, it is clear that at present any study in this field is likely to suffer from misunderstandings and ambiguities.

During the past year, under the direction of Dr. Ralph W. Tyler, Chief Examiner for the University of Chicago, several attempts have been made to evaluate student achievement in scientific thinking. Many items have been constructed and have been included in several examinations. The present paper is a report of one such item, designed to test two aspects of the evaluation of a theoretical principle, namely, whether a given statement supports or has little or no bearing on the principle, and whether the statement is experimental or theoretical. The test item is given in full.

Principle: *In reacting, atoms of both metals and non-metals tend to assume an electron configuration similar to that of the rare gases.*

In the blank before each of the following statements, write

1—if the statement is *true* and *supports* the foregoing principle;
2—if the statement is *true*, but has *little or no bearing on the principle;*

3—if the statement is *false*.

—— (1) The rare gases have "complete" shells.
—— (2) Complete shells are extraordinarily stable.
—— (3) The rare gases form no stable chemical compounds.
—— (4) Elements of main group I in solution readily form ions with a single positive charge.
—— (5) Elements of main group II in solution readily form ions with a double positive charge.
—— (6) Elements of main group II in solution readily form ions with a negative charge of six.
—— (7) Elements of main group VII form in solution ions with a single negative charge.
—— (8) Elements of main group VI readily form in solution ions with a positive charge of six.
—— (9) Metallic elements are good conductors of electricity.
——(10) Non-metallic elements are poor conductors of electricity.
——(11) Ions of elements of groups I and II are chemically unreactive.
——(12) Ions of elements of group VII are more reactive than the free elements.
——(13) Most metallic elements are solids at ordinary temperatures.
——(14) Some metallic elements show more than one valence.
——(15) Non-metallic elements form compounds with other non-metallic elements.
——(16) Metallic elements form compounds with other metallic elements.
——(17) Some non-metallic elements are gases.
——(18) Many elements consist of mixtures of isotopes.
——(19) Molten salts are good conductors of electricity.
——(20) Salts are highly ionized in solution.

Reconsider the statements which you marked *1* or *2* and mark further

4—if the statement is *experimental evidence;*
5—if the statement is a *theoretical assumption or deduction.*

This item was included in three comprehensive examinations on three distinct academic levels. No special instruction on the scientific method was given on any of these levels. The courses on each level and the examinations for these courses may be described briefly as follows.

(*A*) *The High-School Physical Science General Course.*—This is a two-year course for grades 11 and 12. It is an integration of physics, chemistry, astronomy, and geology. The chemistry content is about thirty per cent. of the course, most of which is taught during the twelfth year. The examination for the twelfth year was four hours in length and was taken by sixty students.

(*B*) *The College Physical Science General Course.*—This is a one-year course for university freshmen or sophomores. It is an integration of physics, chemistry, astronomy, geology, and mathematics. The chemistry content is somewhat over twenty-five per cent. The examination was six hours in length and was taken by five hundred thirty students.

(*C*) *The College Chemistry Sequence.*—This is a series of three courses, consisting of two courses in inorganic chemistry and one course of either elementary organic chemistry or elementary qualitative analysis. The examination was six hours in length and was taken by one hundred twenty students.

Table 1 gives the percentage of each group making the various responses. It may be noted that the sum of columns 1, 2, and 3 is equal to 100; and that the sum of columns 4 and 5 is also equal to 100. For example, in the college general course, seventy-four per cent. of the five hundred thirty students considered the first statement, namely, "The rare gases have 'complete' shells," as true and supporting the stated principle. Twenty-four per cent. considered the statement true but thought it to have little or no bearing on the principle. Two per cent. were completely wrong and considered the statement false. Of those indicating that the statement is true (*i. e.*, either response 1 or 2) ten per cent. considered the statement experimental, while ninety per cent. considered it theoretical.

TABLE 1

PERCENTAGE OF STUDENTS IN EACH OF THE THREE COURSES MAKING EACH RESPONSE

	College General Course (530 Students)					*Chemistry Sequence (120 Students)*					*High-School Course (60 Students)*			*General*	
Statement	*1*	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*
1	*74*	24	2	10	*90*	*78*	22	0	9	*91*	*75*	22	3	9	*91*
2	*77*	20	3	47	*53*	*83*	15	2	47	*53*	*80*	18	2	58	*42*
3	*22*	51	27	*96*	4	*20*	62	18	*93*	7	*31*	61	8	*98*	2
4	*71*	24	5	55	*45*	*91*	7	2	79	*21*	*87*	13	0	52	*48*
5	*71*	24	5	54	*46*	*91*	9	0	80	*20*	*85*	15	0	48	*52*
6	6	6	*88*			0	2	*98*			0	2	*98*		
7	*70*	21	9	55	*45*	*91*	8	1	75	*25*	*82*	16	2	50	*50*
8	6	7	*87*			9	3	*88*			10	3	*87*		
9	15	*84*	1	*99*	1	13	*87*	0	*99*	1	13	*87*	0	*100*	0
10	11	*83*	6	*99*	1	7	*91*	2	*98*	2	10	*88*	2	*100*	0
11	*11*	4	85	79	*21*	*51*	11	38	94	*6*	*13*	2	85	89	*11*
12	27	33	*40*			12	11	*77*			32	20	*48*		
13	4	*94*	2	*98*	2	0	*100*	0	*97*	3	0	*98*	2	*98*	2
14	23	*67*	10	*61*	*39*	13	*82*	5	*66*	*33*	20	*75*	5	*68*	*32*
15	19	*63*	18	*98*	2	30	*68*	2	*98*	2	38	*37*	25	*95*	2
16	9	*43*	48	*98*	2	11	*52*	37	*97*	3	22	*31*	47	*100*	0
17	7	*90*	2	*97*	3	2	*93*	5	*97*	3	5	*93*	2	*98*	2
18	8	*79*	13	*47*	*53*	1	*86*	13	*51*	*49*	2	*66*	*32*	*44*	*56*
19	*22*	*58*	20	*99*	1	*19*	*74*	7	*99*	1	*13*	*80*	7	*48*	2
20	*40*	59	1	*57*	*43*	*43*	56	1	62	*38*	*25*	61	14	50	*50*

The numbers in italics represent the answers which the staff have agreed on as the best answer in each case.

In this table the italicized responses are those which ten experts associated with the courses either as instructors or as examiners have deemed as the best answers. Where no agreement among the experts could be obtained, as in items 14 and 19, more than one alternative answer has been allowed.

TABLE 2

FURTHER ANALYSIS OF RESPONSES BY STUDENTS RECEIVING EACH LETTER GRADE IN COLLEGE GENERAL COURSE

Statement	*Response*	*All Students**	*A**	*B**	*C**	*D**	*F**
1	1	74	82	79	72	69	58
1	5	90	100	94	87	87	82
2	1	77	87	84	78	58	46
2	5	53	85	61	43	35	46
3	1	22	42	28	16	14	6
4	5	45	43	54	47	38	25
5	5	46	43	54	49	42	19
6	3	88	100	95	88	73	54
11	5	21	21	29	7	17	67
12	3	40	71	50	29	28	17
14	4	61	85	62	56	49	53
18	4	47	62	50	42	39	39
20	1	40	60	48	33	26	29
20	5	43	63	48	40	29	28

* All figures given are in percentages.

For each academic level, each response has been further analyzed to determine how each group of students receiving a given letter grade has answered the

question. Table 2 gives a detailed analysis on representative responses, made by students of the college general course. Thus while statement 1 was considered theoretical (response 5) by ninety per cent. of the total group of five hundred thirty students, it was so considered by one hundred per cent. of the A's, by ninety-four per cent. of the B's, by eighty-seven per cent. of the C's, by eighty-seven per cent. of the D's, and by only eighty-two per cent. of the F's.

INTERPRETATIONS

Distinction between True and False Statements.—It is evident from Table 1 that students do not experience great difficulty in distinguishing between true (response 1 *or* 2) and false statements. Statements 12 and 16 are notable exceptions. In all cases, however, the agreement with the answer key is better, the higher the scholastic ability of the students. Thus in question 12, while only forty per cent. of the students in the college general course recognized the statement as false, seventy-seven per cent. of the students in the college sequence recognized it as such. Furthermore, in the college general course, seventy-one per cent. of the A's, but only seventeen per cent. of the F's recognized it as false.

Distinction between Whether a Statement Supports or Has Little or No Bearing on the Principle.—There is wide disagreement among students on this distinction. In nearly all cases, however, the majority of the answers agree with the answer key. Furthermore, the higher the scholastic ability, the greater the agreement with the answer key. Thus in statement 2, while seventy-seven per cent. of the entire group agreed that the statement supported the principle, eighty-seven per cent. of the A's and only forty-six per cent. of the F's agreed. Likewise, the percentage of answers agreeing with the answer key is greater for the college chemistry sequence than for the college general course.

Distinction between Fact and Theory.—In regard to this distinction, the statements fall into one of three categories.

The first category consists of statements in which essentially all students agree. Statements 3, 9, 10, 13, 15, 16, 17, and 19 are clearly experimental, while statement 1 is clearly theoretical. These statements are also those upon which the experts agreed without any difficulty. We may conclude, therefore, that the students have no difficulty in making the distinction in cases in which the statement is obviously either theoretical or experimental.

The second category consists of statements in which there is wide disagreement among the students, but the agreement with the answer key is better, the higher the scholastic ability. Statements 2, 18, and 20 are of this category.

Statement 20, for example, has been considered theoretical by but forty-three per cent. of the students of the college general course. Detailed analysis shows, however, that sixty-three per cent. of the A's and only twenty-eight per cent. of the F's have answered it as theoretical. Similar relations obtain in the other statements and among students of the other two courses.

It is significant to point out that in this respect the increased training of three college chemistry courses did not enable the students of the college chemistry sequence to do better than the students of the general courses. It seems as though, the greater the training in chemistry, the greater the tendency to regard as experimental, statements such as "Complete shells are extraordinarily stable."

The third category consists of statements 4, 5, 7, and 11. While in these statements there is a trend for better agreement with the answer key, the better the scholastic ability, nevertheless there is a great deal of confusion. It seems that the word "ion" is widely considered as referring directly to experiment.

Finally, the question may be raised to what extent these responses are significant and to what extent they are due to chance. No definite answer can be given to this question. However, in test items in which one of two alternatives must be answered, even if chance operates fully, the wrong response is rarely made by more than fifty per cent. of the population. The fact that in this test many "wrong" responses were made by more than fifty per cent. of the students indicates a definite bias in the "wrong" direction.

In conclusion, the findings may be summarized as follows. Students have little difficulty in distinguishing between true and false statements. They have some difficulty in deciding whether a given statement supports or has little or no bearing upon a given principle. In distinguishing between experimental and theoretical statements they have little difficulty if the statement is obvious, but experience considerable difficulty if the statement is not obvious. Increased training in chemistry does not help in this distinction. In all other distinctions, students do better, the longer their training in chemistry, and the higher their scholastic standing. More research is needed before these findings can be considered as established.

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ARE THERE RULES *in the* HISTORICAL DEVELOPMENT *of* CHEMISTRY?[1]

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THE development of chemistry is connected with so many varied motives and reasons: religious, economic, personal, that it must seem as difficult to find rules in this development as it would be to find rules in the course of political events of history. Besides, for the progress in chemistry the observations of details are much more important than the development of general theories. How can we hope to find a rule for the fact that Louis Pasteur was attentive enough to see the differences in crystal shape between the isomeric tartrates?

In searching for rules in the historical development of chemistry, we cannot avoid the field of hypothesis. This might not seem especially objectionable in a science which is so justly proud of its solid fundament of facts. But, being theoretical as compared with actual experimental chemistry, the history of chemistry seems to shrink from becoming theoretical to the second degree by trying to develop theories. Such are the arguments which can be raised against the purpose of this essay. Let us now consider the reasons which might favor such an enterprise.

(1) Theories or rules would facilitate a systematic arrangement of the historical facts.

(2) This would constitute a great help in coördinating and grasping the historical events. No one can promise a rule or theory for the fact that Boyle's "Sceptical Chemist" had to appear in 1661. But some of the contents of this book can perhaps be made easier to understand and distinguish if we consider it in connection with a general development.

(3) It is not to be expected that the rules which we may find will be generally accepted without discussion; but it is this discussion which is necessary to improve our findings and to lead to something better.

(4) One object of scientific theories can scarcely be performed by the rules we may find for historical developments and that is the prediction of the immediate future. It would be very important if, by considering the rules of development, we could, if only in a very small way, achieve what political history has seemed unable to do: namely, to learn from the past for our future work. How difficult that would be can be proved from the history of catalysis. It might seem to us that at least one important analogy to it had been developed long before the creation of this notion. I mean Albrecht von Haller's (1708–1772) discussions of "irritability," by which "a very slight stimulus produces a movement altogether out of proportion to the original disturbance." But this physiological notion had no influence on the contemporary and following chemistry.

As an experiment, I try to crystallize a number of rules.. They do not form a system, because I do not pretend that they are complete or that the different rules are based on one another or are closely connected with one another. The six rules which I want to discuss briefly can be designated as follows:

(1) *Continuity.*—The separation of matter or qualities into discontinuous, minute units is followed by a gradual approach to continuity.

(2) *Analogy and Reversion.*—New notions start from analogies, outgrow them to become self-evident, and are later often changed by a Copernican reversion.

(3) *Attributes and Substances.*—Fundamental qualities are explained by fundamental substances (principles). They are modified by attributes which can subsequently become new fundamental substances.

(4) *Isolation and Integration.*—The development of

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the art of isolating produces the tendency to integration.

(5) *Particles and Shapes.*—Models of matter develop from differences in the total shape of the otherwise uniform particles to specific arrangements of specifically different units.

(6) *Generalization.*—One-sidedness in its tendency to generalization contributes to its own rectification.

RULE 1. CONTINUITY[2]

The tendency to approach a realization of continuity can be traced through the development of the atomic theory which destroyed the former meaning of the word atom just at the time when it was first scientifically established in other respects. Further, it can be found in the advance from the three or four primitive elements to the system of ninety-three elements with many times this amount of isotopes between.

Another explanation of the trend to continuity could be found in the development of plastics in so far as here coherent films and threads are produced instead of the individual crystals which dominated chemistry more exclusively before the last few decades.

If these developments were represented graphically their general form would be naturally the same, showing a very sudden rise in the last few decades. The same would be true of any other expression for the development of chemistry, for instance, of the number of chemists, publications, or patents in chemical fields.

RULE 2. ANALOGY AND REVERSION

The first discovery of an analogy is an event of great bearing. Generally it becomes a matter of simple translation once the code for it is found. Just then, when the formerly surprising discovery is turned into a matter of routine and seems to be too evident for further proof, the time comes when exceptions and deceptions are found and a total reversion is prepared. Such fundamentally different things as light and matter are first connected by analogies. Newton writes,[3] "Spirit of Wine has a refractive Power in a middle degree between those of Water and oily Substances, and accordingly seems to be composed of both, united by Fermentation; the Water, by means of some saline Spirits with which 'tis impregnated, dissolving the Oil, and volatizing it by the Action. And as Light congregated by a Burning-glass acts most upon sulphureous Bodies, to burn them into Fire and Flame; so, since all Action is mutual, sulphurs ought to act most upon Light."

It was Newton, too, who considered colors and sounds as analogous. E. Mach criticizes how physicists in the early nineteenth century tried to develop this further,[4] "Obgleich nun Fresnel die Wichtigkeit der Dimension der Wellenlängen vollkommen klar gestellt hatte, so war dies wenige Dezennien nach seinen Publikationen doch wieder vergessen. Wie hätte man sonst in fast allen physikalischen Schriften lesen können, dass der Schall in bezug auf die Fortpflanzung, Reflexion und Brechung sich ganz wie das Licht verhält? Wie hätte man diese Behauptung durch Experimente mit Schallspiegeln und Schalllinsen stützen können, die nur unter ganz besonderen Umständen gelingen, sonst aber illusorisch sind?"

It will be remembered that a hundred years ago Liebig predicted that organic chemistry would be merely a matter of routine and, as we may call it, of translation. That was a few years after the analogy of organic chemistry to notions developed in inorganic chemistry helped so much, for instance in Bunsen's work on the organic compounds of arsenic.

Here we find one of the characteristic difficulties in trying to expose such rules. Bunsen published the work just mentioned in 1837, but already in 1828 Berzelius pointed to the difficulties in attempting to find analogies between organic and inorganic nature.

BERZELIUS TO MITSCHERLICH, FEBRUARY 22, 1828[5]

"Die bisher befolgte Weis, die Produkte der organischen Natur ganz wie diejenigen der unorganischen aufzustellen und zu behandeln, istdie vornehmlichste Ursache der Unordnung in der Pflanzenchemie und der Schwierigkrit, die Details derselben klar aufzufassen und im Gedächtnids zu behalten . . ."

And about forty years later Kekulé explained how he had to abandon the explanation of aromatic substances by analogies with fatty substances.[6]

This shows an important general feature of all these rules. They do not describe the movement of the whole of chemistry at one time and the tendencies in all fields of this vast science. The chemistry of one group of substances could be in the first phase, that of discovering analogies, while others may already have reached the stage where reversion begins. We can exemplify this in the development of the chemistry of fats. This group of substances was united under the notion that one common principle exists in all of them, the principle which makes them fatty. After Chevreul crystallized the different kinds of fatty acids and demonstrated their individualities, the old notion of the fatty principle was overcome. This revolution turned out to be a reversion. The old substantial principle had to be abandoned; instead, a new one was found, not a substance, but a principle of structure.

RULE 3. ATTRIBUTES AND SUBSTANCES

This shows that some developments can be considered under several of our rules at the same time. For instance, we see in this example a similar use of substantial principles as in many other fields. They develop from an original simplicity, which makes them startling and evident in one, to more complicated methods of explanation. Sulfur once was an alchemistical element.

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[2] FÄRBER, "Der Stetigkeitsgedanke," *Osiris*, **3**, 47–68 (1937).

[3] "Opticks," 4th ed., London, **1730** (reprinted by G. Bell & Sons, Ltd., London, **1931**) p. 275.

[4] MACH, "Prinkipien der physikalischen Optik," J. A. Barth, Leipzig, **1929**, p. 380.

[5] Ges. Schriften, von E. VON MITSCHERLICH, hg. von A. Mitscherlich, E. S. Mittler u. Sohn, Berlin, **1896**, s. 82 *seq.*

[6] *Ann.*, **137**, 129 (1886).

Soon it had to be split into different kinds of modified sulfur until each of these modifications claimed its recognition as distinct elements.

The whole development of radioactive substances can be understood under this general rule.

Originally some of them were substances invented in order to explain the cause of alpha and beta activities and the simplification of radiation graphs. Uranium X_1 and Uranium X_2 bear a certain historical analogy to the different kinds of mercury which centuries before designated some hidden qualities in matter.

RULE 4. ISOLATION AND INTEGRATION

Obviously this rule has some fundamental connection with the first one, inasmuch as isolation and integration can be considered from the point of view of discontinuity and continuity. In a very general manner it can be said that the isolation of chemical substances leads to a completing of their system and therefore the "integration" of chemical substances in science as well as in technic. There the integration consists in assembling large quantities of these isolated units of substance resulting sometimes in new problems and discoveries. This integration of large quantities has for instance led to the discovery of new compounds made from acetylene, as by-products in the manufacture of acetic acid.

RULE 5. PARTICLES AND SHAPES

In 1773 T. Bergman developed a theory to explain the nature of the calkspar. The whole rhomboeder is not only the form of the large crystals as we see them but also the form of the smallest particles of which this mineral is built. Wollaston, on the contrary, considered the structural elements of crystals as mathematical points surrounded by forces of attraction and repulsion (1813). Already at that time the theory seemed to be abandoned which tried to explain chemical and physical qualities of substances by the shape of their molecules. This theory is closely related to the notion of signatures which served to explain the physiological action of leaves and fruits from plants according to their resemblance to organs of the human body.

But as I pointed out before this does not mean that in every respect such notions had to be condemned as obsolete and that recurring to them should be considered as a medieval trend in chemistry, proof of which is the rôle which the shape of molecules plays in modern explanations of lubricating oils.

RULE 6. GENERALIZATION

As Whewell explained in his famous book,[7] "residual phenomena" are often responsible for new discoveries. From remote corners discoveries are made which extend or try to extend over the whole field of chemistry. It is not by developing general thoughts that general theories are found in chemistry, but from concentrating upon hitherto neglected and perhaps unimportant details that new systems of theories develop sometimes. The tendency to explain everything from one point of view which makes use of analogies according to our Rule 2 and in some respects is a development as outlined in Rule 4, has sometimes, not only the result of overthrowing existing theories, but often to correct its inherent one-sidedness just by attempting to extend it over the entire field, and this not only in chemistry but in other sciences, too.

This points to one peculiarity common to these six rules. They are not confined to chemistry; they are not specific enough. It may be one of the propositions of the further development to go deeper into specializations, but at the present time it may be an advantage to restrict the attempt to find rules to such generalities. It serves as a connection to the history of other sciences, and it grows out of the unity of them all. Our Rule 2, for instance, can explain a certain generality of simultaneous events in the development of physics as well as zoölogy or mineralogy: The difference between Cuvier's theory of incomparable types and Geoffroy Saint-Hilaire's "unity of plan" or theory of analogs in zoölogy about 1830 corresponds to a similar controversy between Berthollet and Proust mainly between 1801 and 1806. Comparative anatomy[8] was created nearly at the same time that comparative chemistry found relations between inorganic and organic substances and developed the notion of homologous series of substances.[9]

This is the only rule we can find up to now which connects the place of the scientific event with the time at which it took place. It would be very difficult to try to explain, for instance, why Avogadro's theory had to wait until Cannizzaro revived it. We may learn from such events the necessity for repeated proclamations of new findings which Avogadro had neglected or of a concerted effort in collaboration which was achieved at the conference of 1860.

But we cannot hope to find a general rule for the reactions which the knowledge of the present stage of chemistry at any time provoked in contemporaneous scientists.

[7] WHEWELL, "History of the inductive sciences," London, **1837–47.**

[8] OWEN, "Lectures . . .," Longmans, Brown, Green, and Longmans, London, **1843,** "On the archetype and homologies of the vertebrate skeleton," printed for the author by R. and J. E. Taylor, **1848.**

[9] SCHIEL, *Ann.*, **43,** 107 (1842); DUMAS, *Compt. rend.*, **15,** 935 (1842); GERHARDT, "Précis de chimie Organique," Fortin, Masson et Cie, Paris, **1845,** Vol. 2, p. 489.

Knowledge is proud that he has learnt so much; Wisdom is humble that he knows no more.—COWPER

SOME FAMOUS BALANCES[1]

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"Der Mann, der recht zu wirken denkt,
Muss auf das beste Werkzeug halten."
GOETHE

WHEN Virgil wrote *"Arma virumque cano"* he set an example that could well be followed by the historians of chemistry. Without appliances the chemist is practically helpless, without equipment the science could never have developed beyond the stage of philosophical fantasy. Nevertheless, the histories have paid slight attention to the "arms" that made possible the victories won by the men of chemistry.

Artists commonly represent the chemist as addicted to the use of the retort. This is fair practice with respect to the alchemists, who customarily analyzed substances by subjecting them to destructive distillation, but it is absurd when continued by the modern commercial artist. He should know that the retort has long since gone out of style, that chemistry for almost two centuries has been typified by the balance.

"Nothing tends so much to the advancement of knowledge, as the application of a new instrument. The native intellectual powers of men in different times are not so much the causes of the different success of their labours, as the peculiar nature of the means and artificial resources in their possession."[2] The popular belief that the use of the balance was introduced into chemistry by Lavoisier has no foundation.[3]

"There is a certain justification for designating the period of chemistry since Lavoisier as the period of quantitative investigation, but this designation is superficial rather than factual. The distinction of the new from the old chemistry is not that it was only in the later period that men began to weigh or to use the balance—chemists have done this in all periods—but rather that in the earlier period chemical knowledge was not sufficiently advanced to make possible the determination of the weights of the constituents of the majority of the compound substances."[4]

"The conception of composition, as we now understand it, had not taken form. Careful and searching examinations of a few chemical occurrences were required, and precise statements of the results were necessary before satisfactory hypotheses could be constructed, in terms of which fuller descriptions might be given of the facts established by experiment. What was needed was not explanation but description; it is so easy to explain, so difficult to describe."[5]

"But, if, as is generally admitted, chemistry only took rank as a science when it made quantitative work its basis, then Lavoisier must be put before anyone else as having directed it into this road, and led it a considerable distance."[6]

Courtesy of The Procter and Gamble Company

THE VERDICT OF THE BALANCE
FROM AN OLD PROCTER AND GAMBLE IVORY SOAP ADVERTISEMENT, HARPERS' MAGAZINE, 1883.

This pen and ink sketch was again used in an Ivory Soap advertisement in the November, 1886, issue of the "Century," where it was stated, "The advantage of using an article that is pure and always uniform, is, you are always certain of having the same satisfactory results. Eight prominent professors of chemistry, of national reputation, have analyzed Ivory Soap, and the variation in each is so trifling that the quality of the Ivory may be considered reliably uniform."

The historical background seems to be that the slogan "99$^{44}/_{100}$% Pure" was obtained in a report submitted by a prominent Eastern independent laboratory about 1880. A little later a sample was sent to eight chemistry professors who, after analysis, gave their blessing to the new product. The illustration purports to show the jury of eight in action in the laboratory. This, of course, is pure imagination, as the men were in various colleges throughout the country, when they sampled and analyzed the soap.

[1] Presented before the Division of the History of Chemistry at the ninety-ninth meeting of the A. C. S., Cincinnati, Ohio, April 9, 1940.

[2] DAVY, "Collected works," London, **1840**, Vol. IV, p. 37.

[3] See, for instance, WALDEN'S essay, "Mass, Zahl und Gewicht in der Chemie der Vergangenheit," *Ahren's Sammlung, N. F.*, **8**, (1931); KOPP, "Geschichte der Chemie," Vieweg, Braunschweig, **1844**, Vol. 2, p. 68.

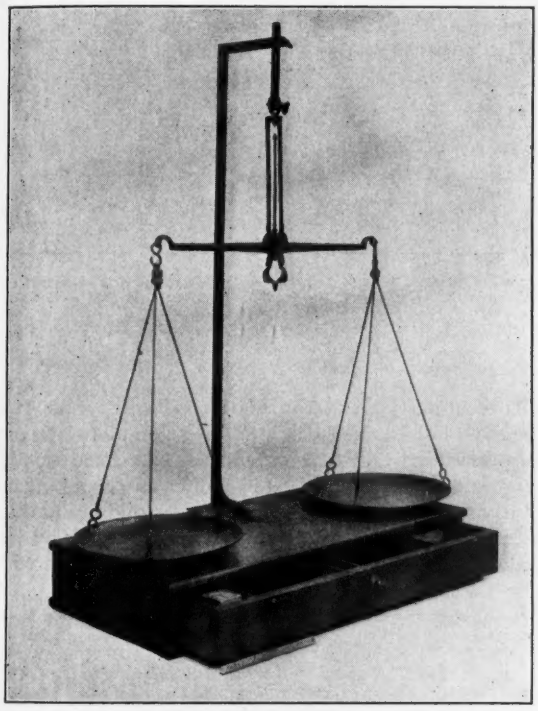
[4] VOLHARD, *J. prakt. Chem., N. F.*, **2**, 20 (1870).

[5] MUIR, "History of chemical theories and laws," John Wiley & Sons, Inc., London, **1909**, p. 48.

[6] FREUND, "The study of chemical composition," Cambridge University Press, Cambridge, **1904**, p. 59.

Like religions, the natural sciences have relics, and among the relics pertaining to chemistry there are balances made famous either because of the men who used them or because these instruments played an important part in outstanding researches. Some years ago the writer began to collect photographs of such balances. The collection is far from complete; almost any chemist can suggest items that should be included.

The purpose of this paper is not to trace the history of the analytical balance or its use by chemists, but rather to point out that a fairly good summary of the progress of chemistry can be obtained by emphasizing the arms rather than the man.



(Reproduction by courtesy Science Museum, London)

FIGURE 1.—JOSEPH BLACK'S BALANCE (REPLICA)

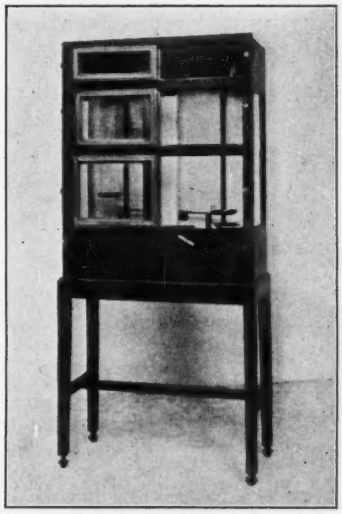
I. JOSEPH BLACK (1728–1799)

It is fitting that this series of sketches begin with Black, whose classic study (1754) of the part played by carbon dioxide in the change from caustic to mild alkalies is "the first example we possess of a clear reasoned series of chemical researches where nothing was taken on trust, but everything was made the subject of careful quantitative measurement."[7]

"Others before him had used the balance for studying chemical reactions, but whenever a gaseous substance had, unknown to them, entered into the reaction as a reagent or as a product, they had been defeated. Black, on the other hand, trusted first and foremost to his balance and to the principle of the conservation of mass, making search for chemical participants in the reaction only after the balance had showed him that they were there to be sought."[8]

"We may indeed regard Black's work as constituting the beginning of modern chemical science."[9]

Although Black had, so to speak, worked "balance in hand," his account[10] tells nothing of the weighing equipment used. The results were given no closer than one grain, so that a fairly rough instrument was adequate. A balance of this type, known to have been used by Black, is preserved in the Scotch Royal Museum at Edinburgh, but there is no reason to believe that it was used in the work on magnesia alba. A replica of this balance is exhibited in the Science Museum at South Kensington, London, and is pictured in Figure 1.



(Photograph by courtesy Science Museum, London)

FIGURE 2.—HENRY CAVENDISH'S BALANCE (NOW AT THE ROYAL INSTITUTION, LONDON)

It is of passing interest to note that Black devised a balance useful for weighing small quantities. He described this in a letter (Sept. 18, 1790) to James Smithson. The novel feature was a calibrated beam fitted to receive globules of gold of known weight and also brass rings, which by their position enable the operator to vary their effective mass. No examples of this early rider balance are known.[11]

[7] RAMSAY, "The gases of the atmosphere," The Macmillan Co., London, **1896**, p. 60.

[8] MASSON, "Three centuries of chemistry," The Macmillan Co., New York City, **1926**, p. 115.

[9] DONNAN, Introduction to RAMSAY'S "Life and letters of Joseph Black," Constable and Co., Ltd., London, **1918**.

[10] This is now readily accessible as No. 1 of the Alembic Club Reprints, Edinburgh, **1898**.

[11] A sketch of the balance and the text of the letter may be found in the *Annals of Philosophy, N. S.*, **10**, 52 (1825). See also SPETER, *Z. Instrumentenkunde*, **50**, 204 (1930).

II. HENRY CAVENDISH (1731–1810)

"It has been said of Cavendish that his theory of the Universe seems to have been that it consisted *solely* of a multitude of objects which could be weighed, numbered, and measured, and the vocation to which he considered himself called was to weigh, number, and measure as many of those objects as his allotted three-score years and ten would permit. . . . . Whenever we catch sight of him we find him with his measuring-rod and balance, his graduated jar, thermometer, barometer, and table of logarithms, if not in his grasp, at least near at hand. Many of his scientific researches were avowedly quantitative. . . . . It seems indeed, to have been impossible for Cavendish to investigate any question otherwise than quantitatively." . . . . "He was indifferent to elegance of form in his apparatus, which, provided it were accurately constructed, might be clumsy in shape and of rude materials. He insisted, however, on its perfect accuracy."[12] At the death of Cavendish his apparatus passed to his cousin and heir, Lord George Cavendish, who presented much of it to Humphry Davy. Included was the balance (Figure 2) that had been constructed according to Cavendish's own design by Harrison. Although of unwieldy appearance it was used to produce results of considerable accuracy.[13] From Davy it passed to I. G. Children, then to Alexander Garden, from whom it was received (1868) by the Royal Institution, in whose museum it is now exhibited.

(Photograph, courtesy of E. F. Smith Memorial Collection, Philadelphia, Pennsylvania)

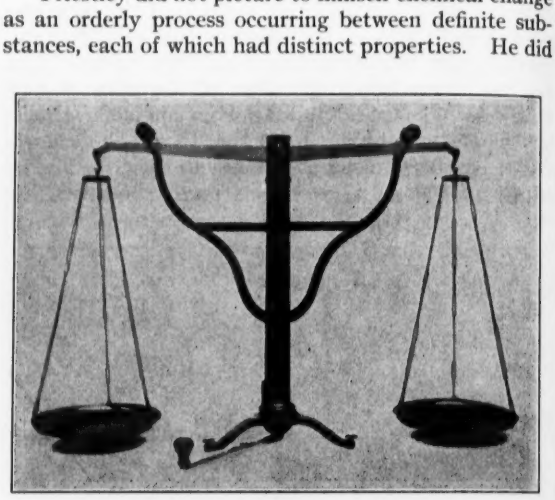
FIGURE 3.—JOSEPH PRIESTLEY'S BALANCE (NOW AT PRIESTLEY MUSEUM, NORTHUMBERLAND, PENNSYLVANIA)

[12] WILSON, "The life of Henry Cavendish," printed for the Cavendish Society, London, **1851**, pp. 178, 186.

[13] "Cavendish produced results of an accuracy which would rank high even now, and which for that time was almost miraculous." FREUND, *op. cit.*, p. 59.

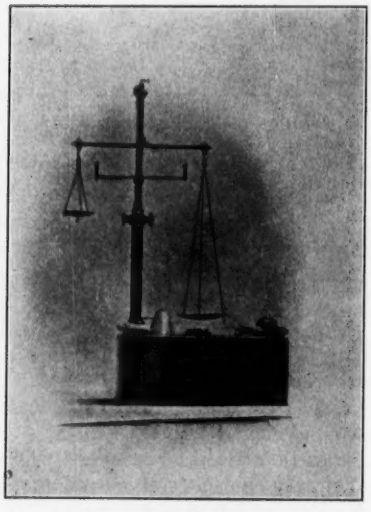
III. JOSEPH PRIESTLEY (1733–1804)

"Priestley did not picture to himself chemical change as an orderly process occurring between definite substances, each of which had distinct properties. He did not accurately weigh the materials he used and the products he obtained; he did not attempt to account for everything that took part in the transformation he examined."[14] However, he could do good quantitative work when he felt the necessity, and his unusual manipulative skill, both in chemistry and physics, makes it obvious that he could handle a balance with



(Photograph from "Musée Centennal de la Classe 87. Arts chimiques et Pharmacie à l'Exposition Universelle Internationale de 1900 à Paris")

FIGURE 4.—LAVOISIER'S LARGE BALANCE (NOW AT THE CHATEAU DE LA CHAMFORTIERE, SARTHE)



(Photograph, courtesy of Science Museum, London)

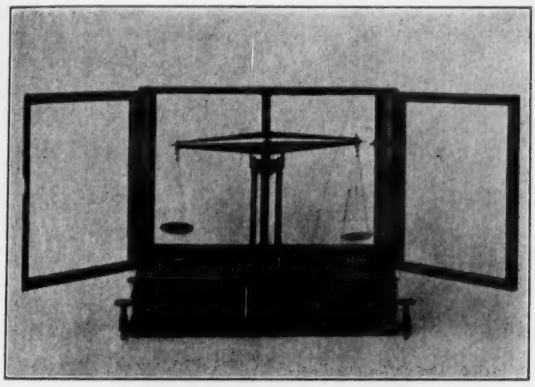
FIGURE 5.—JOHN DALTON'S BALANCE, MADE BY ACCUM (NOW AT MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY ROOMS)

[14] MUIR, *op. cit.*, p. 38.

dexterity and certainty. If he did not make many weighings in his chemical investigations, the reason lay in the fact that he, like chemists in general, have no pleasure in the mere accumulation of data without apparent purpose.[15] The balance (Figure 3) brought to America by Priestley in 1794 was kept in the family for many years. It was then given to Edgar F. Smith by the Misses Annie and Jean Priestley, great-great-granddaughters of Priestley. In 1926 Professor Smith presented the balance to the Priestley Museum at Northumberland, Pennsylvania, where it is now preserved.[16]

IV. A. L. LAVOISIER (1743–1794)

So much has been written about Lavoisier's recourse to the balance in solving chemical problems that it is sufficient for the present purpose to give no more than



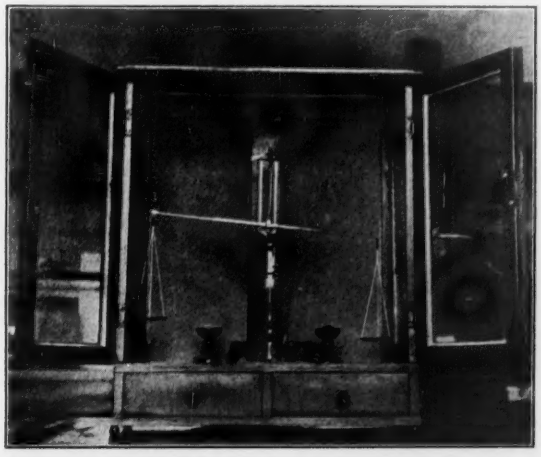
(Photograph, courtesy of Science Museum, London)

FIGURE 6.—BALANCE USED BY SIR HUMPHRY DAVY. MADE BY FIDLER (NOW AT THE ROYAL INSTITUTION, LONDON)

the following. "Lavoisier brought to the study of chemistry the equipment most needed at this time—the habits and mental attitude of the trained physicist. We shall often have occasion to see that chemistry has gained enormously by the influence of those whose point of view has been preëminently physical, men who do not care to prepare new compounds or discover new reactions, but who prefer to weigh and measure, and in this way gain insight into the mechanism of chemical changes already familiar on the qualitative side."[17]

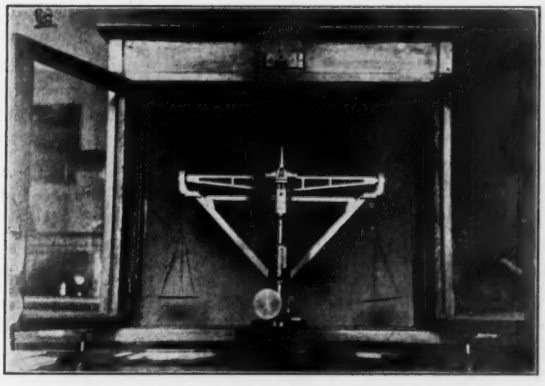
In one of his earliest papers, Lavoisier stated that the chemist had at his disposal a means of learning the precise quantities of concrete materials involved in their experiments. "La balance est une épreuve sure qui ne saurait les tromper."[18]

He wrote, "As the usefulness and accuracy of chemistry depends entirely upon the determination of the weights of the ingredients and products before and after experiments, too much precision cannot be employed in this part of the subject; and, for this purpose, we must be provided with good instruments. As we are often obliged, in chemical processes, to ascertain, within a grain or less, the tare or weight of large and heavy instruments, we must have balances made with peculiar niceness by accurate workmen—I have three sets, made by Fortin,[19] with the utmost nicety and excepting those made by Ramsden of



(Photograph by courtesy Swedish Royal Academy of Sciences)

FIGURE 7.—BALANCE USED BY BERZELIUS (EARLY PERIOD). MADE BY SAUTER, STOCKHOLM (NOW AT BERZELIUS MUSEUM, FRESCATI, STOCKHOLM)



(Photograph, courtesy of Royal Swedish Academy of Sciences)

FIGURE 8.—BERZELIUS' BALANCE (LAST PERIOD). MADE BY LITTMANN, STOCKHOLM (NOW AT BERZELIUS MUSEUM, FRESCATI, STOCKHOLM)

[15] HARTLEY, *J. Chem. Soc.*, **1933**, p. 918, gives a summary of those parts of Priestley's work that mark him as one of the earliest physical chemists.

[16] BROWNE, J. CHEM. EDUC., **4**, 197 (1927).

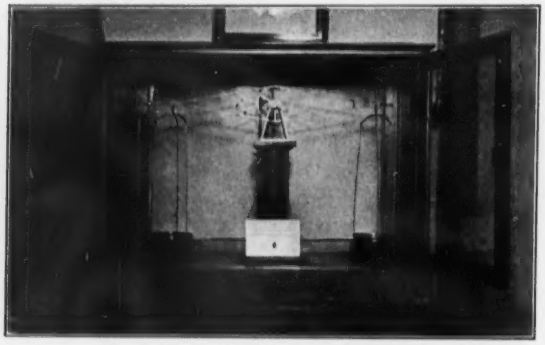
[17] MOORE, "History of chemistry," 3rd ed., McGraw-Hill Book Co., Inc., New York City, **1939**, p. 93.

[18] "Oeuvres de Lavoisier," Imprimerie Impèriale, Paris, **1865**, Vol. 3, p. 157.

[19] Jean Fortin (1750–1831) Parisian fine-mechanic, perfected and devised many physical and astronomical instruments. His balances, among the first of real precision, were prized highly.

London, I do not think any can compare with them for precision and sensibility. The largest of these is about three feet long in the beam for large weights, up to fifteen to twenty pounds; the second, for weights of eighteen or twenty ounces, is exact to one-tenth part of a grain, and the smallest calculated for weighing about one gros[20] is sensibly affected by the five-hundredth part of a grain."[21]

Lavoisier's apparatus since Madame Lavoisier's death (1836) has been in the possession of her heirs, the de Chazelles family. Some of the larger instruments are exhibited in Paris at the Conservatoire des Arts et



(Photograph, courtesy of Gesellschaft Liebig Museum)

FIGURE 9A.—LIEBIG'S "BRAUNSTEIN WAAGE" (NOW AT LIEBIG MUSEUM, GIESSEN)

Metiers, but the bulk of his appliances, including the three balances, are on view at the Chateau de la Chamfortière in the Sarthe, whither they were removed in 1935[22] from the Chateau de la Caniere in Auvergne, where they had been for many years, and where they were seen and described by Truchot[23] and by Lusk.[24]

The large balance (Figure 4) cost six hundred livres (approximately two hundred fifty dollars in present purchasing value). With a load of ten kilograms it will give an accuracy within twenty-five milligrams. The beam oscillates before two fixed scales, and the position of two marked points, one on each side of the central knife edge, is observed through telescopes. Speter, who has given a rather extended discussion of Lavoisier's balances and weights,[25] raised the interesting question, "Could Lavoisier have been able to gain his scientific triumphs so surely and so quickly if he had not possessed delicate balances and accurate weights and a knowledge of good weighing technic?" This thought is in line with Davy's statement, "Without facilities for pursuing his object, the greatest genius in the experimental research may live and die useless and unknown."[26]

V. JOHN DALTON (1766–1844)

"It would be unadvisable to claim for Dalton a high station in experimental chemistry. He possessed neither the mental habits and tastes for extreme exactitude nor the unrivalled manual expertness which characterized Davy, Wollaston, and Prout."[27]

"He was by no means gifted as an experimenter, and financial reasons long made it necessary for him to work with the crudest apparatus, often of his own construction; yet all these handicaps could not prevent him from discovering several of the laws which rest at the very foundation of the science."[28]

The balance (Figure 5) used by Dalton is of simple construction, unprotected by a case, and can be arranged for use as an hydrostatic balance. Dalton, by a codicil in his will, bequeathed "all his chemical and other philosophical apparatus" to his pupil and friend, Dr. Charles W. Henry, who, in turn, presented

FIGURE 9B.—DETAILS OF LIEBIG'S "BRANNSTEIN WAAGE"

the balance to the Manchester Literary and Philosophical Society. It is still in their possession.

VI. HUMPHRY DAVY (1778–1829)

Davy never believed in atoms and substituted "proportions" for Dalton's word atom to avoid theoretical annunciations.[29] He made determinations of chemical proportions, basing his figures largely on experiments made by himself and his brother, John.

[20] 1 grain = 1/60 gross = 1/480 ounce = 1/5760 pound. 1 grain = 0.0729 gram. The French pound of that time = 375 grams.

[21] LAVOISIER, "Elements of chemistry," translated by Kerr, Creech, Edinburgh, **1790**, p. 297.—Lavoisier promised to acquaint the Academy with the details of his balances, but never did so.

[22] *Nouvelles de Chimie*, November, 1935.

[23] TRUCHOT, *Ann. chim. phys.*, [5] **18**, 289 (1879).

[24] LUSK, *Proc. Am. Med. Assoc.*, **85**, 1246 (1925).

[25] SPETER, *Z. Instrumentenkunde*, **54**, 56 (1934).

[26] DAVY, *op. cit.*, Vol. 8, p. 356.

[27] REILLY AND MACSWEENEY, *Sci. Proc. Roy. Soc. Dublin*, **19**, 139 (1929).

[28] MOORE, *op. cit.*, p. 115.

[29] GREGORY, "The scientific achievements of Sir Humphry Davy," Oxford University Press, London, **1930**, p. 131.

In his "Elements of Chemical Philosophy" (1812) he promised to publish the details of the labors "I have carried on during the last twelve years in analytical chemistry," but this promise was never kept.

The balance (Figure 6) used by Davy and also by Thomas Young (Professor at the Royal Institution, 1801–03) was described by both of them.[30] It was

(Photograph, courtesy of Professor Paul Pascal, University of Paris)

FIGURE 10.—BALANCE USED BY J. B. DUMAS IN HIS STUDIES ON THE ATOMIC WEIGHT OF CARBON, THE COMPOSITION OF AIR, THE COMPOSITION OF WATER (NOW AT THE SORBONNE, PARIS)

made for the Royal Institution by Fidler. Like many other balances of the time, it had a conically shaped hollow beam. Davy found that it would turn easily with one five-hundredth grain when loaded with one hundred grains on each pan. The balance is on view at the Royal Institution.

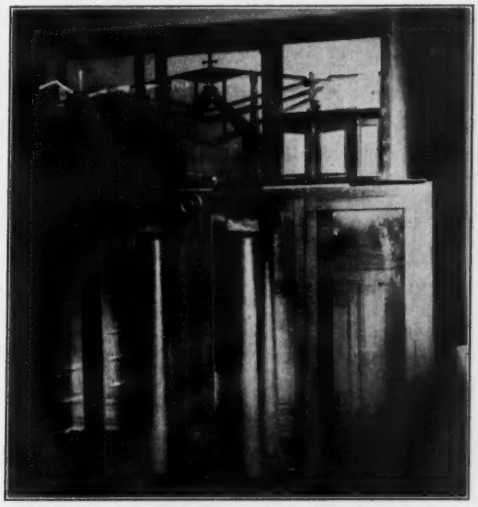
VII. J. J. BERZELIUS (1779–1848)

If anyone deserves the title "father of quantitative analysis," the honor must be given to Berzelius. Though analytic and synthetic methods existed before him, their precision was not of the order requisite for the solution of the problems raised by Dalton's laws. Even the notables were not in agreement as to the quantitative composition of even important compounds.[31] Reliable methods had to be created without regard to expenditure of time and labor. With inferior apparatus, with scarcely any help from chemical manufacturers in the supplying of pure materials and reagents, Berzelius, with undaunted patience, consummate skill, and most honest criticism of himself eventually produced the first trustworthy list of numbers representing the proportions in which the elements combine. He himself made atomic weight determinations of

(Photograph, courtesy of Professor Paul Pascal, University of Paris)

FIGURE 11.—BALANCE USED BY DUMAS FOR VAPOR DENSITY DETERMINATIONS (NOW AT THE SORBONNE)

about forty elements and determined the composition of about two thousand compounds. His results were not without some errors which remained for correction by his successors—but it is not so remarkable that there



(Photograph, courtesy of Professor Paul Pascal, University of Paris)

FIGURE 12.—BALANCE USED BY DUMAS AND SAINTE-CLAIRE-DEVILLE IN THEIR STUDIES RELATIVE TO THE PREPARATION OF THE PLATINUM-IRIDIUM STANDARD METERS (NOW AT THE SORBONNE)

were errors as that these errors were on the whole so few and of such relatively small importance.[32]

[30] YOUNG, "Lectures on natural philosophy," London, **1845**, Vol. 1, pp. 97, 765; DAVY, *op. cit.*, Vol. 5, p. 17.

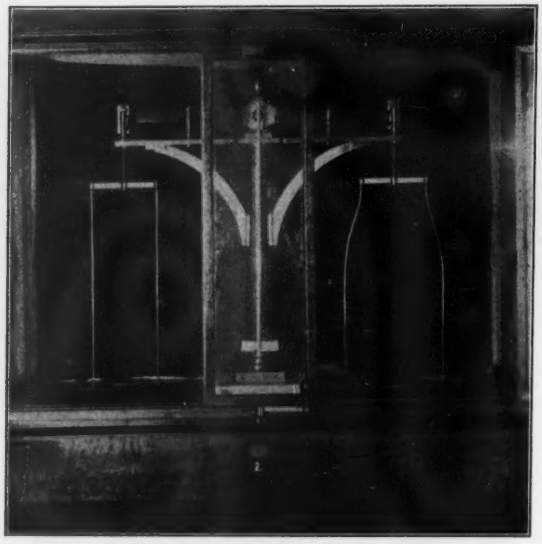
[31] For examples see SÖDERBAUM's essay on Berzelius in BUGGE's "Das Buch der grossen Chemiker," Verlag Chemie, Berlin, **1929**, Vol. 1, p. 431.

[32] MALLETT, "Chemical Society Memorial Lectures," Gurney and Jackson, London, **1901**, p. 18,

The Berzelius Museum, assembled by the Swedish Academy of Sciences at Frescati near Stockholm, contains quite a few balances used by this master analyst. Two of these have been selected for inclusion in this discussion. Figure 7 shows the oldest instrument. It is of the simplest construction. The long beam and the suspension of the pans by threads reveal its early type. The balance used in the last period of Berzelius' life is shown in Figure 8. The beam is shorter and is of the now-common truss design. The readings were made with the aid of a magnifier. On the whole, this instrument does not differ greatly from some of the older balances still in use in certain laboratories.

VIII. JUSTUS LIEBIG (1803–1873)

No chemist had a better appreciation of the value of analytical chemistry than Liebig. He was an expert in devising analytical procedures and equipment, and also



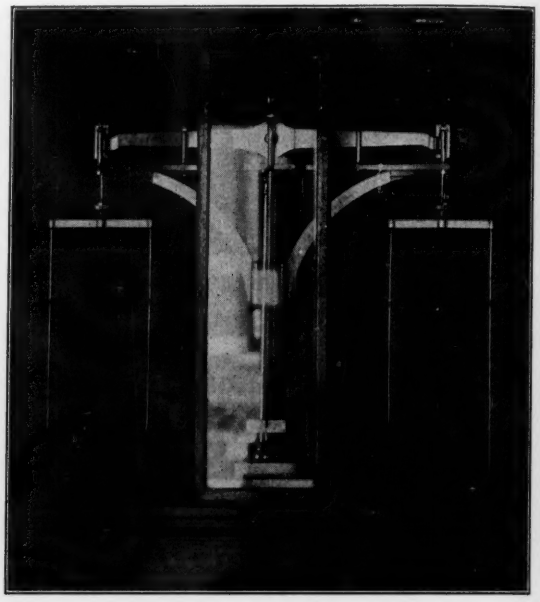
(Photograph, courtesy of Professor Jean Timmermans, Brussels)

FIGURE 13.—STAS' BALANCE (LARGEST) MADE BY SACRÉ, BRUSSELS (NOW AT UNIVERSITY OF BRUSSELS)

in making analyses. He was often asked to undertake important analyses, and his signature on a report carried real weight. The balance was an important item in the equipment of his laboratory. With its aid he did much to unravel the tangled skein of organic chemistry; by intelligent analyses he found means of furthering the progress of industrial, agricultural, and physiological chemistry. His own experience had taught him the latent power of this instrument; he knew whereof he spoke when he wrote "..... the balance, that incomparable instrument, which gives permanence to every observation, dispels all ambiguity, establishes truth, detects error, and shows us that we are in the true path."[33]

[33] LIEBIG, "Familiar letters on chemistry," 4th ed., Walton and Maberly, London, 1859, p. 126.

The Liebig Museum at Giessen[34] has several balances that were used by Liebig. The best preserved is the one shown in Figure 9. It was used principally in the analysis of pyrolusite and so is known to the Museum authorities as the "Braunstein Waage." Liebig was



(Photograph, courtesy of Professor Jean Timmermans)

FIGURE 14.—STAS' BALANCE MADE BY SACRÉ, BRUSSELS (NOW AT UNIVERSITY OF BRUSSELS)

partial to long-beam balances, and it was a standing comment at Giessen that a cigar could be smoked between swings.

IX. J. B. DUMAS (1800–1884)

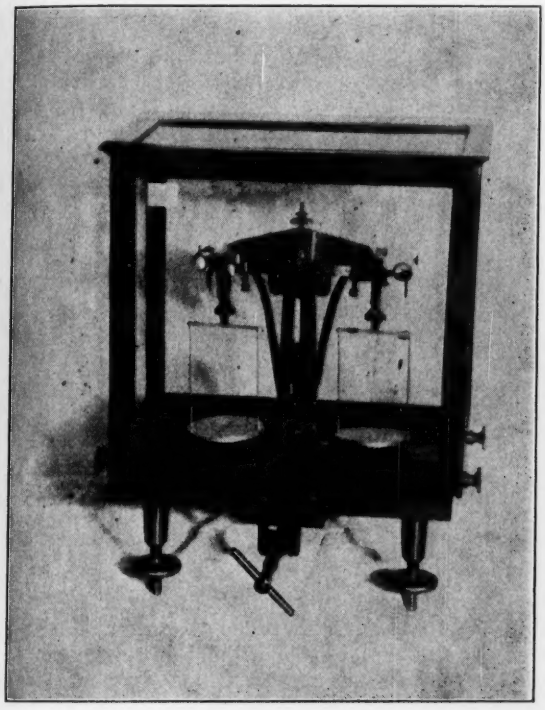
Analytical chemistry is indebted to Dumas for an accurate method of determining nitrogen in organic materials; the physical chemists remember him chiefly for his method of measuring vapor densities. His greatest contribution along analytical lines was his determination of the relative atomic weights of about thirty elements. He was led into this field by the results obtained when the Berzelius value for carbon (76.432, O = 100) consistently gave impossible results. Dumas and Stas obtained the much better value 74.956. Encouraged by this correction, he decided that the whole list of Berzelius values needed revision. This work occupied him many years. Particularly important was his determination (1842) of the oxygen: hydrogen ratio in water. With Boussingault's aid he made accurate determinations of the ponderal composition of the air.[35] In these three studies Dumas used the balance shown in Figure 10. It was con-

[34] SOMMER, J. CHEM. EDUC., 8, 211 (1931).

[35] For an excellent popular account of Dumas' work see THORPE, "Essays in historical chemistry," The Macmillan Co., London, 1923, p. 318.

structed for him, and has a sensitivity of one milligram when loaded with one kilogram in each pan. The balance shown in Figure 11 was used for his work on vapor densities.

After the original French metric standards were found to be in error, an international commission was



(Photograph, courtesy of Professor V. Tistchenko, University of Leningrad)

FIGURE 15.—MENDELÉEFF'S SHORT-BEAM BALANCE MADE BY SALLERON, PARIS (NOW AT UNIVERSITY OF LENINGRAD)

organized in 1872 to supervise the preparation of new prototype meters. Dumas and Ste. Claire Deville were entrusted with the task of preparing the platinum-iridium ingots from which the bars were made. Their work was completed in 1882; the bars were made, the copies compared and finally delivered to the various governments in 1889.[36]

The tremendous balance (Figure 12) was constructed for this work. The height is 2.2 meters, the length two meters, the width 0.7 meter. Each meter bar was weighed in the horizontal and the vertical position. The sensitivity is one milligram with a load of ten kilograms in each pan. The three Dumas balances are now preserved in the laboratories of mineral chemistry of the University of Paris.

[36] *Cf.*, GLAZEBROOK, "Dictionary of applied physics," The Macmillan Co., London, **1923**, Vol. 3, p. 585, for a history of the revision of the metric standards. See also MATHEY, *Chem. News*, **39**, 175 (1879), for an account of the preparation of the bars.

X. J. S. STAS (1813–1891)

This great chemist introduced a new era into quantitative procedures; his approach to these problems was far superior to anything that had previously been attempted. Most of his time for forty years was spent in determining the atomic weights of a dozen elements. He was led to this work by the share he had had in determining with Dumas the atomic weight of carbon, and by belief in the validity of Prout's hypothesis. His experiments were conducted with a patience, care, and accuracy that are almost appalling, and nothing short of reading his own accounts can convey an adequate idea of the care and ingenuity he expended on the purification of all the materials used and the elaborate precautions against mechanical loss. He studied the methods to be used with extreme rigor and found and applied refinements upon the older procedures. For him no pains were too great, no toil too severe that could render more accurate the results which others might take and trust, as the basis of their researches, however little the greater part of mankind might feel interested in or even know of his quietly pursued investigations. By his work he proved that the laws of constant proportions, of multiple proportions, of reciprocal proportions are mathematically accurate expressions of facts that hold good throughout the whole range of chemical interactions."[37]

(Photograph, courtesy of Professor V. Tistchenko, University of Leningrad)

FIGURE 16.—MENDELÉEFF'S BALANCE FOR WEIGHING GASES (NOW AT THE UNIVERSITY OF LENINGRAD)

[37] MALLET, *op. cit.*, p. 18.

Stas employed unusually large weights of interacting materials. For instance, 77–405 grams of silver were converted into nitrate and weighed as such; 139–259 grams of silver chlorate were converted into silver chloride; and so forth. The balances were of excellent construction and unusually satisfactory both as to sensitivity and steadiness. Stas seems to have been the first to apply *in full* to his weighings the proper correction for buoyancy in air.

Stas described his balances in his classic paper on his atomic weight determination.[38] "The largest [Figure 13] of the three balances, made expressly for my researches, will carry a load of five to six kilograms on each pan, and with this enormous load will indicate with certainty a difference in weight of one milligram. With a load of two to three kilograms on each pan, it turns in a very noticeable manner with a difference in weight of three- to four-tenths of a milligram." The other Stas balance shown here (Figure 14) has a capacity of five hundred grams on each pan, and indicates a difference under this load of two-tenths of a milligram. These balances are preserved at the University of Brussels.[39]

XI. D. I. MENDELÉEFF (1834–1907)

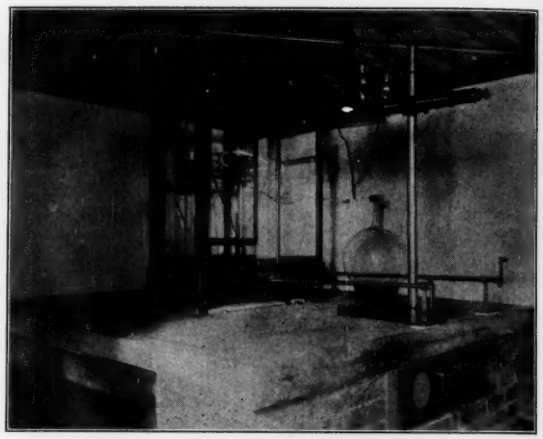
Mendeléeff was convinced that reactions are fundamentally connected with the physical and mechanical properties of the atoms and molecules. His chemical interest was largely in the field nowadays labeled physical chemistry. He made important experimental contributions to this field: specific volumes, specific gravities of solutions, elasticity of gases at low pressures, and so forth. For his ordinary work he used a long arm Oertling (London), capacity two hundred grams, sensitivity one-tenth of a milligram, or a Sartorius of the usual type. For special purposes he had available instruments of unusual design.

Figure 15 shows a balance made from Mendeléeff's own design.[40]

It has a short beam (twelve centimeters) and is capable of carrying considerable loads. With one kilogram on each pan, one milligram gives a swing of fifteen divisions on the scale placed behind the crosshairs at the end of the beam. The balance is small enough to be covered by a bell jar that can be evacuated. Obviously it cannot accommodate bulky objects and was designed for such special purposes as the verification of weights. The second balance shown (Figure 16) was used by Mendeléeff for work on gases. These balances are preserved at the University of Leningrad.

XII. E. W. MORLEY (1838–1923)

The publication of Morley's monumental "On the densities of hydrogen and oxygen and on the ratio of their atomic weights"[41] was the capstone of eleven years of arduous toil. This indefatigable worker frequently spent the greater part of the night in the laboratory, and his health broke down under the strain of overwork before the researches were completed. These wonderfully accurate determinations, which are the peers of the results obtained by Stas for other elements, were attended by difficulties even greater than those encountered by the great Belgian chemist. Much time was spent in the detection of constant errors, in studying the details of the methods, in careful calibration of the instruments, and in making doubly sure as to the purity of the materials.[42]



(Photograph, courtesy of the Smithsonian Institution)

FIGURE 17.—BALANCE USED BY E. W. MORLEY. MADE BY RUEPRECHT, VIENNA (NOW AT SMITHSONIAN INSTITUTION, WASHINGTON)

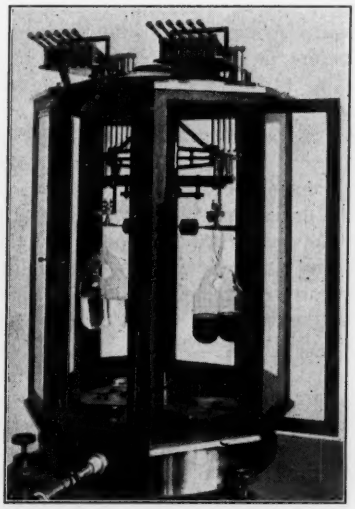
Two balances were used. The first, made by Becker, Rotterdam, was presented to his alma mater by Morley and is still at Williams College. The second, and more interesting, (Figure 17) was constructed specifically for this work by Rueprecht, Vienna. The cost, five hundred fifty dollars, was borne by the Smithsonian Institution and the balance lent to Morley. After he completed his work it was returned to Washington. It had a capacity of twelve hundred grams in each pan, and the sensitivity was adequate. The gases were weighed in globes suspended from the pans and hung in an insulated closet under the balance. An ingenious long-distance mechanism enabled Morley to change the globes from one pan to the other, so that the Gauss method of reversals could be used without touching the globes. The parts of the dismantled apparatus can be seen at Western Reserve University, where this outstanding piece of work was carried out.

XIII. HEINRICH LANDOLT (1831–1910)

Lavoisier's enunciation of the law of conservation of mass during chemical reactions was far from justified

[38] STAS, "Oeuvres completes," Muquardt, Brussels, **1894,** Vol. 1, p. 315.
[39] TIMMERMANS, J. CHEM. EDUC., **15,** 357 (1938).
[40] SALLERON, *Compt. rend.*, **80,** 378 (1875).
[41] MORLEY, *Smithsonian Contributions to Knowledge,* **29** (1895).
[42] BOOTH, *Ind. Eng. Chem.*, **15,** 194 (1923); CLARKE, *J. Chem. Soc.*, **1923,** 3435; FREUND, *op. cit.*, 72, 192, 313.

by his own experiments, which deviated from the theoretical by 0.25 to two per cent. This fundamental tenet, whose origins are ancient, was established within 0.002–



(Photograph, courtesy of the late Professor W. Marckwald, Berlin)

FIGURE 18.—BALANCE USED BY H. LANDOLT MADE BY RUEPRECHT, VIENNA (NOW AT LABORATORY OF PHYSICAL CHEMISTRY, UNIVERSITY OF BERLIN)

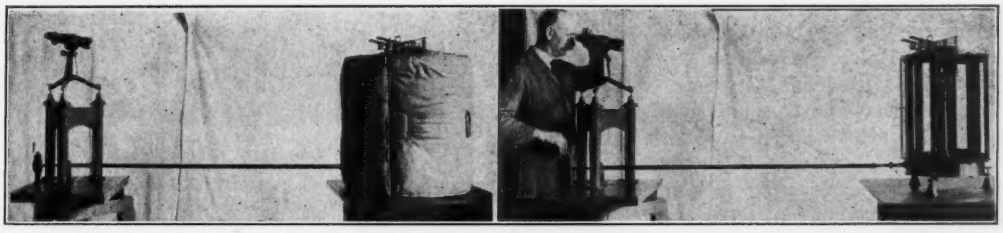
0.004 and 0.01 per cent. by Stas and by Morley, respectively; but they assumed the validity of the law and took the minute deviations as proving the high purity of their reacting materials.

"But neither Stas's nor Morley's experiments were undertaken with a view to investigating the validity of the law of the conservation of mass, and as a matter of fact, they are particularly ill adapted to that purpose. .... In experiments made by Landolt with the object of testing the law of conservation of mass, the conditions could be specially adapted to this purpose, and hence a more rigorous proof given."[43]

Landolt's study of this problem extended over a period of almost twenty years (1890–1908) and the final report was not issued until after his death.[44] The reactions were carried out in sealed vessels, with a degree of care and consideration of details that probably has never been equaled. Of the last forty-eight trials, twenty-three showed an increase in weight, twenty-five a decrease, but the deviations in only three cases exceeded the maximal experimental error (±0.03 mg.) and then by only 0.002 to 0.008 mg. Landolt concluded that, with respect to the fifteen reactions he studied, no change in the total weight had been established. Any deviation must be less than 0.01 or 0.001 mg. and so beyond the experimental limits of investigation.

The central point in this research was the balance (Figure 18). It probably is the finest instrument of its kind that has ever been made. Landolt, who knew what he needed, after extensive travels in Germany, France, and England, entrusted the commission (1901) to Rueprecht of Vienna. They discussed the details of the progressive refinements in fifty letters and frequent conferences. The capacity of the balance is six hundred grams in each pan, the beam is thirty centimeters long.[45] The work was carried out in a room provided with adequate temperature controls. Long-distance (three meters) controls made it unnecessary for the operator to enter the room to change the weights, reverse the loads, and so forth. An overload of one milligram with five hundred grams on each pan gave a scale reading of thirty-five to thirty-eight divisions (millimeters) that could be easily read to one-tenth through the telescope. It is reported that Landolt made more than 27,000 readings to establish the accuracy of "this beautiful instrument that gives me the greatest joy." The maximal weighing error was ±0.001–0.005 mg. Much of the work had to be done at night because of traffic vibrations.

The studies with this balance were carried out in Berlin, first (1901–05) at the Physikalisch-Chemisches Institut of the University, and then (1906–08) at the Physikalisch-Technische Reichsanstalt.



(Photograph, courtesy of the late Professor W. Marckwald, Berlin)

FIGURES 18A AND 18B.—BALANCE USED BY LANDOLT, DETAIL

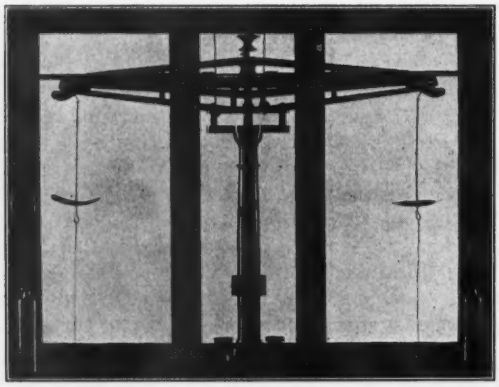
[43] FREUND, *op. cit.*, p. 102.

[44] LANDOLT, "Über die Erhaltung der Masse bei chemischen Umsetzungen," *Abhdl. Akad. Wissenschaften*, **1910**, Berlin, Phys.-math. Klasse. Abk. I. See also the detailed biography of Landolt by PRIBRAM, *Ber.*, **44**, 3337 (1911).

[45] A detailed technical description is given in FELGENTRÄGER, "Theorie, Konstruktion und Gebrauch der feineren Hebelwaage," Julius Springer, Berlin, **1907**.

XIV. LORD RAYLEIGH (1842–1919)

Lord Rayleigh, like Stas, derived the inspiration for his epochal chemical work from a desire to test Prout's hypothesis. In 1882 he wrote, "The time has perhaps come when a redetermination of the densities of the principal gases may be desirable—an undertaking for which I have made some preparation."[46] This study, which promised to be a drab affair, turned out to be the basis of one of the most exciting chapters in the history of chemistry. The establishment of the fact that "chemical" nitrogen differed in density (1.2505 gm. per l.) from that of "atmospheric" nitrogen (1.2572) put Rayleigh on the track of some disturbing element that was present in the air in considerable amounts (1.3 per cent. by weight). The discovery of an unknown substance that had been under the very noses of the chemists reads almost like a detective story. "At long last was captured the arch-eluder, who had escaped detection, though his haunts had been searched continually by chemists since chemistry began. He had taken the measure of Scotland Yard but had forgotten Sherlock Holmes, and when he appeared the game was up. What made the discovery especially remarkable was that it was made by the use of the balance, an instrument which is, and always has been, in every chemical laboratory, and in the use of which chemists are very expert. It was not discovered, though it might have been, by the spectroscope as so many other elements have been. . . . . The discovery of argon was much more important than the ordinary discovery of an element; it was the discovery of a new type of element, one which has been of fundamental importance in the development of the structure of the atom."[47]

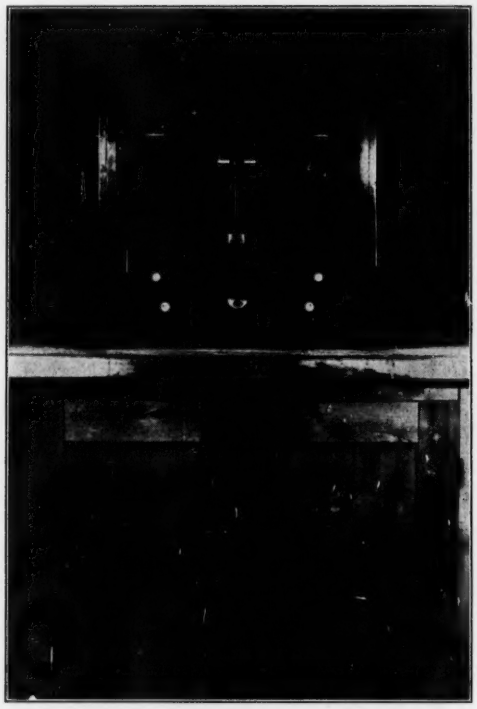


(Photograph, courtesy of the late Baron Rayleigh)

FIGURE 19A.—BALANCE USED BY LORD RAYLEIGH MADE BY OERTLING, LONDON (NOW AT TERLING PLACE, ESSEX)

No important work on the weighing of gases had been done since the time of Regnault (1845) and Rayleigh had detected a source of error in these measurements. Every precaution was taken, and years of toil were expended before he felt sufficient confidence to publish his first results. The work was done in the cellar of his house. The balance (Figure 19) was set up on a slate-topped cupboard in which hung the globes containing the gases. The room was waterproofed, and the atmosphere kept dry by the simple expedient of hanging in it well-dried wool blankets. Often these would gain two pounds in twenty-four hours.

The balance was left swinging overnight ready for the temperature to settle down, and the final readings taken the next morning. In his notes on the use of a balance[48] Rayleigh described a method of magnetic damping, but this was not used in this work. The methods of reading and illumination were, however. The balance, globes, and so forth, are still in the cellar at Terling Place, Chelmsford, Essex.



(Photograph, courtesy of the late Baron Rayleigh)

FIGURE 19B.—BALANCE USED BY LORD RAYLEIGH (NOW AT TERLING PLACE, ESSEX)

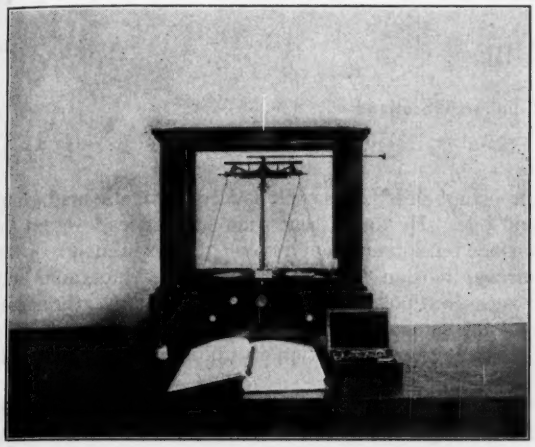
[46] RAYLEIGH, "Life of J. W. Strutt, Third Baron Rayleigh," Edward Arnold and Co., London, **1924**, p. 158. An exceedingly readable, impartial, and detailed account of the discovery of argon is given in this biography of Rayleigh by his son. For the report of the discovery of argon see RAYLEIGH AND RAMSAY, *Chem. News*, **71**, 51 (1895); *Smithsonian Contributions to Knowledge*, **29** (1896).

[47] THOMSON, "Recollections and reflections," The Macmillan Co., New York City, **1937**, p. 397. Rayleigh, a physicist, once said, "If you wish a thoroughly troublesome job, pick out a chemical problem."

[48] RAYLEIGH, "Scientific Papers," Cambridge University Press, Cambridge, **1899–1920**, Vol. 2, p. 226.

XV. THEODORE W. RICHARDS (1868–1928)

Richards, the first American chemist to receive the Nobel Prize, was fond of making the following quotation from Plato, "If from any art you take away that which concerns weighing, measuring, and arithmetic, how little is left of that art." He is most widely known for his work on atomic weights. For a long time the work of Stas was taken as the nearest approach to perfection that had ever been attained, but persistent discrepancies between his values and those of Richards led ultimately to the discovery that Stas's work was vitiated by appreciable errors that were not difficult to trace. Subsequent developments in Richards' laboratory have shown that Stas, though years ahead of his time, was in error by important amounts in nearly all of his work. A new era in analytical accuracy was thus inaugurated by Richards and the students who worked under him."[49] They redetermined the atomic weights of twenty-four elements in the laboratories at Harvard.



(Photograph, courtesy of Professor G. P. Baxter)

FIGURE 20.—BALANCE USED BY T. W. RICHARDS (1890–96) MADE BY TROEMNER, PHILADELPHIA (NOW AT HARVARD UNIVERSITY)

The balance (Figure 20) was employed by Richards in the period 1890–96, and presumably was used in the work on barium, copper, and strontium. For small loads it is accurate to 0.01 milligram, and up to fifty grams to 0.01–0.02 mg. It is not sturdy enough to carry its rated capacity, two hundred grams.

[49] BAXTER, *Science*, **68**, 333 (1928).

A CONVENIENT TYPE OF WASH BOTTLE

RAY WOODRIFF

University of Colorado, Boulder, Colorado

FOR chemical work in which a wash bottle finds constant use, it is important to have one which is as convenient as possible.

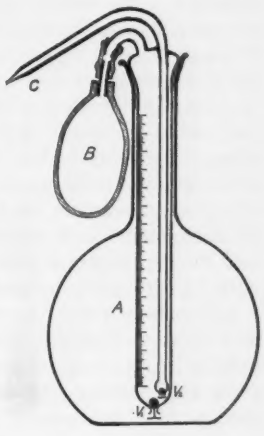
The advantages of the wash bottle are shown here.

(1) The volume of liquid used can be accurately measured.
(2) The amount of wash liquid may be accurately controlled, even down to one drop.
(3) The wash liquid may be directed against the precipitate with great force when desired; however, the force of washing may be easily controlled.
(4) The liquid comes in contact with nothing but glass. Although vapors go down into the rubber bulb, any material loosened by such contact does not fall into the wash liquid.
(5) Use of this wash bottle eliminates the unpleasant necessity of blowing into the bottle, thus enabling one to see better what he is doing. Also burns, or disagreeable fumes from the wash liquid are avoided.

When the rubber bulb, B, is pressed, the pressure in the auxiliary tube, A, is increased, causing valve V_2 to open, thus forcing the liquid from A out through the tube C with a force proportional to the pressure exerted on the bulb, B.

When the pressure on B is released, a partial vacuum is created in A, so that V_2 closes, and V_1 opens, thus refilling A.

The auxiliary tube, A, permits the accurate measurement of the volume of liquid used. This tube which can be made from a test-tube may be ground to fit the flask as shown in the drawing, or may be merely inserted through a cork or rubber stopper. The ground joint or stopper should fit loosely enough to permit the entering of sufficient air to replace the liquid used.



Valves V_1 and V_2 may be made by melting down the end of a thin glass rod to form a bead of the desired size; this is inserted with emery dust and twisted to form a smooth seat. The rod is then cut off to the proper length, the valve is reinserted, and a small cross rod of glass is sealed to the end of the valve to hold it in place.

The EARLIEST HISTORY *of* CAPILLARY CHEMISTRY

I. TRAUBE

University of Edinburgh, Edinburgh, Scotland

THE branch of science called "capillary chemistry" was founded by the author of this paper and developed by Herbert Freundlich (see his excellent standard work on capillary chemistry (*1*)). Hence the saying, learned accidentally by the author, that H. Freundlich was "the father" and I. Traube "the grandfather" of this domain of science.

The earliest paper of Traube dates back to the year 1884 (*2*). At that time significant theories of capillarity were known. In the theories of La Place, Poisson, Gauss, and others, it was assumed that with complete wetting the contact angle of the liquid in capillary tubes was equal to 0. Its cosine would be equal to 1, and hence the meniscus should be a hemisphere. Traube showed in his first papers that this assumption in general was not right (*3*), that the angle changed with the temperature and that even at ordinary temperature the cosine was 1 only for water and certain aqueous solutions.

The experimental work on capillarity at that time was very limited. The works of Quinke, Volkmann, and others may be mentioned. These authors investigated solutions of inorganic salts, acids, and bases, employing generally the method of capillary tubes. In a few cases the dropping method was applied by Quinke and others, but very imperfectly. This method was developed by Traube. His simple instruments, the *Stalagmometre* and the *Stagonometre*, have found general application in science and industry (*4*). If the area from which the drop fell was circular, and its diameter so big that the drop completely wetted this surface, but became detached only from it, very regular drops were obtained. The rate of dropping and the temperature, however, had to be considered. Either the number of drops in a given volume was determined by means of the stalagmometer or the number of calibrations, corresponding to one drop, were determined with the stagonometer, *i. e.*, a calibrated capillary tube with dropping area. According to this principle a medical dropping glass found general application in all countries where dropping glasses are used. The theoretical papers of Th. Lohnstein (*5*), F. Kohlrausch (*6*), and Rayleigh (*7*), and the experimental paper of E. Duclaux (*8*), dealing with the dropping methods, should also be mentioned.

As has been noted, the experimental papers by former investigators (Quinke, Volkmann, and others) related only to inorganic salts, acids, and bases, but as early as 1864 a dispensing chemist, C. Musculus (*9*), had investigated some aqueous solutions of pharmaceutically important substances such as alcohol, acetic acid, soap, and bile. He found that such substances lowered the surface tension and had a much greater influence on the surface tension than salts and other inorganic substances, but polyhydroxy-compounds such as the sugars had the same effect as salts. The merits of Musculus concerning the foundation of capillary chemistry should not be forgotten.

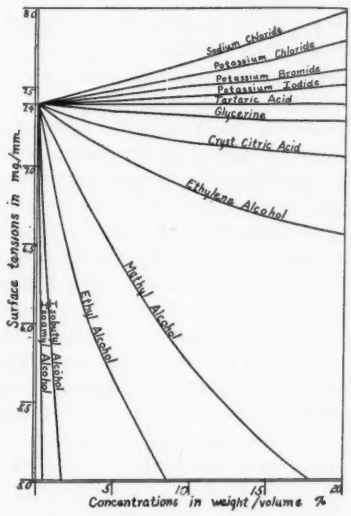
However, a *systematic* examination of aqueous solutions of organic substances had not been made when the present author began his investigations (*10*). These investigations showed that many organic substances, dissolved in water, influenced the surface tension of the solution much more than inorganic salts. While such salts generally *raise* the surface tension of water slightly, many organic substances such as primary alcohols, fatty acids, ketones, esters, and so forth, *lower* the surface tension of water often to a considerable extent. Water-soluble substances were therefore divided into two groups: *surface inactive* and *surface active* substances.

This distinction proved later to be very useful and it can be brought in parallel to the distinction between *electrolytes* and *non-electrolytes*. *Surface active substances especially have to be important because numerous properties of substances are closely related to surface activity.*

The influence of different solutes on the surface tension of water is shown in the accompanying table which was published in 1885 (*11*). The surface tensions, measured by the method of capillary tubes and calculated in mg. mm., are plotted along the ordinates whereas the abscissas show the percentage weights in equal volumes of solution. It is obvious that the salt curves are practically straight lines while those of the capillary-active alcohols are parabolas. It was also shown that the *minutest* quantities of the higher members of a homologous series decrease the surface tension of water. The action is much more pronounced in dilute solutions than at higher concentrations. If the substance is only sparingly soluble the saturated solution shows a surface tension very nearly equal to that of the solute as such. This fact in itself points to a simple relationship between surface tension and solubility, *e. g.*, for isomeric substances (*12*).

Quantitatively it was shown by the author's experiments on aqueous solutions that the surface tension of capillary-active compounds belonging to one homologous series decreased with each additional CH_2 group in a constant ratio which is approximately 3:1 (*13*).

Thus the concentrations of isocapillary solutions in the series of aqueous solutions of alcohols, esters, ketones, ethers, fatty acids, and so forth, were in the ratio $1:3:3^2:3^3\ldots\ldots$ This rule, called "Traube's Rule" generally held true up



to high concentrations of the solutions. The validity of that rule was proved by the author and later on by Forch (*14*), Windisch and Dietrich (*15*), and Sternglanz and Weber (*16*) even for substances of a high molecular weight. Aqueous solutions of $N/9000$ undecylic acid approximately showed the same surface tension as a $N/3000$ solution of caprynic acid and a $N/1000$ solution of nonylic acid. It is seen from these numbers that very small quantities of strongly surface active substances can be analytically determined.

It could be shown that Traube's coefficient 1:3 decreased very gradually for substances of high molecular weight (*17*). In such aqueous solutions as carbon disulfide, carbon tetrachloride, and so forth, not the slightest effect on the surface tension of water could be demonstrated, though it was shown by physiological and other experiments that such substances have a certain solubility in water (*18*). But there are two kinds of solubility.

A substance can be dissolved not only as single particles, but also as complex particles. There can be colloidal distribution, and in many cases an equilibrium between dissolved single particles and dissolved colloidal particles results. In a concentrated solution of amyl alcohol a certain fraction is already in colloidal solution. This fraction is far greater in the solution of a higher alcohol, such as octyl alcohol, where under the ultramicroscope many submicrones are visible which concentrate gradually at the interface between aqueous phase and immersion oils or air, and so forth (*19*). Alcohols and fatty acids of still higher molecular weight dissolve only as colloidal particles which influence the surface tension of water very little or not at all. To give only a few examples: It is possible by cataphoresis to prepare aqueous solutions of nonylic acid which show the same surface tension as that of water. The ultramicroscope reveals that such solutions contain a number of big particles only. These complex particles are broken down by the addition of a few drops of hydrochloric acid. The Brownian movement of a very great number of submicrones can be observed, and the surface tension of the solution which previously was practically equal to that of water falls to about half the value. The same phenomenon is observed when a few drops of an alkali solution are added to an aqueous solution of atropine (*20*), the dissolved particles of which have increased in size through prolonged standing of the solution. The solution which previously had the surface tension of water now shows vivid Brownian movement, and the breakdown of the complex aggregates results in a considerable decrease of the surface tension.

The following theoretical points must be added (*21*). Between the particles of the solute and the solvent van der Waals forces or electric forces are acting as the case may be. The possibilities of attraction are: a_1a_2 and a_1a_1 or a_2a_2. These attractive forces correspond to forces which this author called "Haftintensität" in earlier works. If the attraction a_1a_2 is very great only single molecules will generally be dissolved particularly in dilute solutions. However, the smaller the attractive forces between solvent molecules and solute particles the greater will be the tendency of the solute particles to form complex particles. The greater the surface activity of a compound and the less soluble it is the greater is its tendency to form complexes.

The presence of submicrones in solutions of sparingly soluble substances is shown by the Tyndall beam and the ultramicroscope (*22*). The rule which bears the author's name was first advanced from purely empirical reasons. But it was further shown that it was of importance for a great many scientific, especially biological and technical problems (*23*). As long as these problems have a simple relation to the surface tension, the validity of the rule could also be shown in these other fields. A theoretical explanation of the rule was given chiefly by Irving Langmuir (*24*) in his classical researches. One objection, however, has to be raised. According to Langmuir the rule should not hold for higher concentrations of the solutions but only for dilute solutions. In this case we can assume with Langmuir that the dissolved particles spread horizontally at the interface. However, according to my experimental findings, the rule still holds at rather high concentrations (*25*). This fact in itself shows that a horizontal arrangement of the CH_2 chains is not necessary for the understanding of the rule.

It is sufficient for our case to assume that the intensities of adhesion (*i. e.*, van der Waals numbers a_1a_2) of two successive members of homologous series of surface active substances are in the ratio 1:3 (*26*). The

amounts of work required to bring a dissolved molecule from the interior of the liquid to the surface would then be in the same ratio.

It was found by the author that simple ratios resembling those in homologous series also hold in other respects for the surface tension of aqueous solutions (*27*). Thus we obtain the ratio 1:1 for isomerides of fatty acids and ethers, for normal and iso-fatty acids as well as for alcohols, for the transition of numerous capillary-active amino-compounds into hydroxyl-compounds, and so forth; in other words, when a NH_2 group is replaced by an OH group. The concentrations of iso-capillary solutions of allyl- and propyl-compounds are in the ratio 2:1. There exists a near relation between *surface tension* and *adsorption*.

According to Gibbs' principle the excess of substance accumulated per unit interface as compared to the interior of the solution is $\mu = \frac{c}{RT}\frac{d\sigma}{dc}$ where c, R, T and σ have the usual meanings. Therefore the concentration of surface or interfacial active substances is increased in the surface or interface, and the concentration of surface inactive substances in the surface or interface is decreased. The changes of concentration are corresponding to the surface tension. With increasing surface activity the "chance" of an adsorption in a second phase also increases, and therefore we can postulate a simple relation between surface tension and adsorption. It obviously follows that such a relationship exists if we compare the adsorption isotherms according to the theory of Boedicker-Freundlich with the relative curves of surface tension.

The curves are very similar, but we will not enter here into the particulars of that well-known theory, and we will merely state that this theory of adsorption is certainly important but empirical.

We must also content ourselves by mentioning the brilliant works of adsorption, which were accomplished in a later period of the development of capillary chemistry by the two famous American scientists, I. Langmuir (*24*) and Harkins. Langmuir found that the capillary-active substances are adsorbed at the interface in a regular manner, *viz.*, in layers which he called monomolecular layers. Harkins (*28*) also formulated a regular arrangement of the molecules at the interface by calculating the *work of adhesion* which is exercised by the polar and non-polar groups of the molecules toward the solvent. The beautiful experiments carried out by Adam (*29*) and Rideal (*30*) in connection with Langmuir's theory should not be forgotten. As a result of Langmuir's investigations, it was possible for the first time (*31*) to transfer the gas laws and the van der Waals theory to *two-dimensional* systems. The first experiment in this line was carried out by the author of this communication.

Rona and other authors (*32*) have established that substances of great surface activity can displace substances of less surface activity or surface inactive substances from the surface of the adsorbent. Freundlich (*33*), this author (*34*) and his pupil, Skumburdis, (*35*) have published tables, which show that indeed the relations between surface activity and adsorption are very near, but this is by no means always the case. Thus, for example, the adsorption of many aromatic substances by charcoal is considerably greater than corresponds to their surface activity. The author pointed out that such substances are dissolved partially or completely as colloids, and that these colloidal particles, though they increase the adsorption, do not generally influence the surface tension. This is one of the reasons of the cause for the divergence.

While according to Langmuir the adsorption of capillary-active substances at the interface of water-air takes place in monomolecular layers, for water-soluble as well as for water-insoluble surface active and polar substances, the adsorption of colloidal droplets of oleic acid, and so forth, by powdered minerals (*36*) (lead, felspar, and so forth) was found to take place in thousands of layers. The oil drops adhere much closer to ores such as lead than to minerals such as felspar.

Related to this is the fact that adsorbents such as anthracene and naphthalene frequently adsorb only small quantities of solute from the aqueous solutions. Thousands of layers, however, are adsorbed as soon as substances such as octyl alcohol and caprylic acid are brought into contact with the adsorbent in form of an aqueous emulsion (*37*). On the addition of water it is usually found impossible to separate the droplets from the adsorbent. Even if the adsorbed substance is water-soluble, only single molecules are separated from the adsorbent when it is shaken. The colloidal droplets adhere closely to the adsorbent.

Special attention may be directed to the relations of *surface tension* and *permeability* and/or *osmosis*. When a liquid or dissolved substance is adsorbed by a solid, porous, or gel-like adsorbent, the former will either adhere to the surface of the adsorbent or it will permeate partially or completely into the interior of the solid substance. If the solid, possibly in the form of a gel-like substance, forms a membrane which is surrounded by a layer of liquid on both sides osmosis takes place, and it is of importance to find out the character of the osmotic forces which are responsible for the osmotic process. According to the osmotic theory of van't Hoff—as applied to dilute solutions—and the theory of electrolytical dissociation by Arrhenius which forms a useful supplement to the theory of van't Hoff, the number of particles to be found in solution on either side of the membrane is responsible for the course and direction of the osmotic process. As driving force we have to consider the osmotic pressure, which is found to be equal to the gaseous pressure—the same cause being made responsible for both. Gradually, however, it became apparent that the purely physical theory of osmotic pressure carried with it considerable disadvantages. Whereas the gas molecules move about in a free space, the dissolved molecules in concentrated as well as in *dilute* solution are in continual contact with the molecules of the solvent. There is to a greater or smaller extent considerable attraction between the

molecules of the solute and those of the solvent. Whereas for dilute gases van der Waals magnitudes a_1 and a_2, need not to be taken into account these attractions a_1 and a_2 cannot, as was the case in van't Hoff's theory, be neglected even in very dilute solutions. The theories of van't Hoff and Arrhenius did not take any notice of those intensity factors governing the attractions between solvent and solute, though these factors are responsible for the action of the solutions just as is the case for the number of particles in solutions. The direction of osmosis and the osmotic force as such depends not only on the number of particles but also to a considerable extent on the forces of attraction mentioned above, which correspond to the surface activities of the solute particles (*38*). The *direction* and *velocity* of the *osmosis* as well as the *osmotic equilibrium* are therefore *determined* above all by the *surface tensions* of the *solutions*, a fact which was neglected for a long time. Indeed, it could be shown that in general the time of flow of aqueous solutions through a capillary tube is parallel to the surface tension. At a time when the entire scientific world was in favor of the theory of van't Hoff and that of Arrhenius, the author of this communication was the only one, especially among the German scientists, who pointed out the deficiencies of those theories, which were later indeed shown to exist also by physicists like Bjerrum, Milner, and especially Debye and Hückel and others. As long ago as 1904 and 1908 the author pointed out that when two aqueous solutions were separated by a membrane generally the solution with the lower surface tension permeates through the membrane (*39*). This assumption could be confirmed for numerous processes especially those of a *biological* nature. First of all may be mentioned the digestion and kidney secretion. The stomach and gastric juices normally have a considerably lower surface tension than the blood or blood serum, and the blood in turn has a lower surface tension than the urine. The examination of numerous urines under normal and pathological circumstances led to the results that there is an intimate relation between the functioning of the kidney and the surface tension of the urines (*40*). If in certain diseases of the kidney the surface tension of the urine became too small a counter-action became effective which decreased the activity of the kidneys. The examination of exudates and transudates also confirmed this consideration.

It was shown that for all sorts of osmotic processes, differing widely among themselves, in cells of plants and animals, the osmotic process depended largely on the surface tension of the solution in question. The plasmolytic experiments of Overton (*41*) led to the result that in aqueous solutions the permeation into the cells was hardly noticeable for substances such as salts, sugars, and glycol; that it was slow for glycerol; a little quicker for glycine and acetamide; rapid, however, for monobasic alcohols, esters, and fatty acids. The series of the surface tensions and of the osmotic velocities were the same according to my investigations. Analogous observations were made for the osmosis of red blood corpuscles, and so forth (*42*). These relationships were shown to hold true both qualitatively and quantitatively.

Traube's rule was confirmed by the author and other observers for numerous biological processes, especially for processes which depend on adsorption and osmosis, such as plasmolysis and haemolysis, narcosis of tadpoles, the development of fertilized eggs of sea urchins (*43*), the transition of antiheliotropism of crustaceae into heliotropism, various fermentation processes, oxidation, wetting, and so forth (*44*).

The interesting investigations of Czapek and his pupil Kisch (*44*) showed that cells of leaves died and yeast cells lost their power of budding, if they were introduced into iso-capillary solutions of alcohols, esters, ketones, and so forth, having a definite threshold value. Naturally, chemicals owe their poisonous properties to very different causes, but on comparing the poisonous action of a certain class of medicinals among themselves such as certain alkaloids of the morphine group or of the cocaines, it is possible to say that the substance of higher surface activity shows a stronger toxic and pharmacological action (*45*). Among the most highly capillary-active alkaloid substances are the hydrocupreines investigated by Morgenroth and his collaborators. They are hydroquinine derivatives, such as eucupine, vucine, and so forth. Their enormous bactericidal action is in conformity with their great surface activity (*46*). It has already been mentioned that an aqueous solution of an alkaloid such as atropine, which, when newly prepared, is strongly capillary-active can be made completely inactive on long standing on account of the aggregation of the single particles. Accordingly, the toxicity decreases considerably. Tadpoles only lived for fractions of a minute in the former solution, but for eighteen hours and longer in the inactive solution (*47*). This relation between toxicity or decrease in toxicity and complex formation of the particles dissolved in a medium is very remarkable from the *serological* point of view (*48*). Many problems in pharmacology and allied sciences are closely related to these considerations.

A later series of experiments by myself and my pupils also showed that the rate of permeability of equivalent aqueous solutions of capillary-active substances depends first of all on the surface activity of the solutions (*49*). The rate of permeability and the surface activity are parallel to each other. This finding is of considerable interest especially from the biological standpoint, as it shows how important a factor, the surface tension, or interface tension, respectively, constitutes for all determinations of permeability. Considering how this factor was neglected it is not surprising that van't Hoff's theory broke down especially when applied to biological processes. After the failure of van't Hoff's theory when applied to biology the so-called *lipoid theory* (*50*) aroused much interest.

E. Overton and H. H. Meyer assumed that the surface of all plant and animal cells contained lipoids, and pointed out that the entrance into the cells of substances present in an aqueous solution was dependent on their

solubility in lipoids or rather on their partition coefficient in lipoids and water. No doubt cell osmosis and lipoid solubility are often parallel but this is by no means invariably the case. Furthermore it is doubtful if all cell walls contain lipoids. Indeed it was shown by the author of this communication that the lipoid solubility does play a considerable rôle in connection with cell osmosis, but the driving osmotic force is nothing else than the surface activity or the interface activity, respectively. According to the author's experiments this action is adequate to the rate of permeability in all cases, even where no lipoids can be detected. However, where lipoids are present their action cannot be neglected. As to the *many relations* which *connect* the chapter of surface tension with a very great number of *problems of pharmacology* and *therapy*, of *toxicology*, *bacteriology*, *balneology*, and also *serology*, the reader may be referred to earlier publications (see the foregoing literature).

Finally one other point may be stressed. Pure chemists are accustomed to make constitution solely responsible for the properties and action of the substances. A *Chemotherapeutical* Science grew up which achieved tremendous success. The great achievements of Ehrlich's school might be recalled, but still more so the astonishing successes which have been obtained in recent times in the field of *hormones* and *vitamins*. It was the ingenuity of the most eminent scientists which made it possible to determine the structure of most complicated compounds and which led to a new fruitful era of organic chemistry. Thus it seemed as if only the chemotherapeutical science was entitled to tackle diverse biological and other problems. However, in connection with these investigations, compounds which had nothing in common with respect to their constitution were frequently found to show the same physiological and other effects. Further, substances which exhibit a marked action only in animal physiology were found to be of plant origin and, on the other hand, important plant matters were found in products of animal metabolism.

These facts which appear strange on first sight can only be interpreted in terms of physics. Let us remember that properties such as surface tension, electric potential, and so forth, though they depend on the constitution of the substances in question, can have the same value for compounds that vary considerably in composition. If, furthermore, we consider that different biologically important processes such as adsorption, permeability, osmosis, and so forth, are closely related to surface tension, surface activity, and so forth, we can understand that compounds of different composition sometimes exhibit the same vitamin or hormone action.

Thus the constitution of compounds is of importance only inasmuch as it is the cause for certain physical and chemical properties which can be responsible for their biological and other behavior. In this connection surface tension is of first importance. A *physicotherapeutical* science will have to *supplement* the *chemotherapeutical* one.

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AN INEXPENSIVE VACUUM TUBE OSCILLATOR FOR STUDENT USE IN MEASURING THE CONDUCTANCE OF ELECTROLYTES

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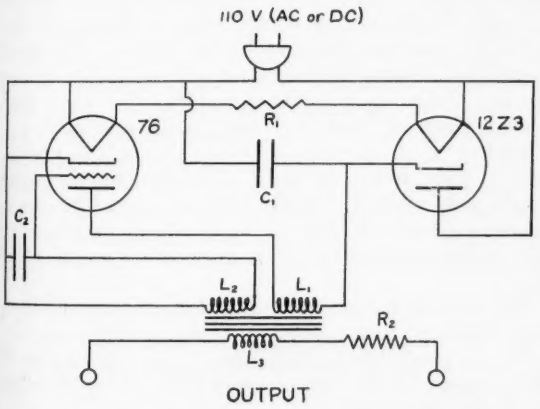
THIS paper describes a source of alternating current for students' use in measurements of conductance which combines certain advantages not possessed by circuits heretofore published. The circuit shown below has the following characteristics. (1) It is easily constructed from a few standard radio parts which are inexpensive and readily obtained. (2) It operates without the use of any batteries, from an ordinary 110-volt line. Either alternating or direct current may be used with equally good results and without any change in the circuit. (3) It is rugged and dependable in operation. (4) It gives an intensity of sound sufficient for use without any amplifier, and makes possible a high sensitivity in the bridge setting when used in a quiet room.



The circuit is represented in the diagram. The 12Z3 tube serves as a rectifier and the 76 as an oscillator. The heater elements of both tubes require 0.3 ampere; they are connected in series with a resistance R_1 of 300 ohms (and 25 watts) to the 110-volt source. The positive potential attained by the cathode of the rectifier is steadied by an electrolytic condenser C_1 of 25 microfarads. The induction coils are obtained from radio supply houses under the name of radiofrequency chokes. The values of the inductances chosen in this circuit are $L_1 = L_2 = 60$ millihenries, and $L_3 = 30$ millihenries. (These are the catalog ratings, and not the actual values of the inductances as the coils are used in this apparatus.) The three coils are stacked one above the other on a soft iron rod about 4 mm. in diameter; the iron has the function of increasing the mutual inductance between the coils and bringing the frequency down into the audible range. The condenser C_2 should have a capacity of 0.25 microfarad to give a frequency of the order of 1000 cycles per second. It is essential that the right terminal from the coil L_2 be connected to the grid of the oscillator tube. Perhaps the simplest way to determine the correct connection is to try both possible directions. In only one direction will oscillations be produced. The third coil is provided to bring out the alternating current in a circuit insulated from the power supply so that the various parts of the Wheatstone bridge may be safely handled while the oscillator is in operation. A resistance R_2 of about 1000 ohms is placed in series with this coil in order to prevent the oscillations from being choked out when small resistances are being measured in the bridge.

The intensity of the sound produced by this circuit is so great that one cannot comfortably wear a pair of headphones attached directly across the output. The sensitivity of the adjustment of the bridge with this alternating current source is greatest for the measurement of resistances of about 1000 ohms, where the point of balance can be located within 0.1 per cent. The range through which resistances can be measured with an accuracy of one per cent. or better extends from 10 to 10,000 ohms. If the set is to be used with direct current, the right-hand terminal in the diagram should be connected to the positive pole, although no damage would result from accidentally reversing the connection.

The total cost of the parts required to construct this oscillator is less than five dollars at current market prices.

A LECTURE EXPERIMENT *on* DYEING[1]

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MANY introductory courses in chemistry, particularly those designated as "general" chemistry courses, include a certain amount of organic chemistry, the admitted objective being to give to the student some appreciation of the field of organic chemistry and of some organic industrial processes. This material usually includes some of the simple fundamentals of the chemistry of dyeing, and also studies of some of the more common natural and synthetic fibers. We have used with much success a lecture demonstration which in one experiment illustrates some of these fundamentals of dyeing, as well as the difference in the chemical nature of different fibers. It is a demonstration which never fails to stimulate and arouse the interest of the student. The procedure used, known as cross-dyeing, is a common one in the textile industry. It has also been used successfully as a demonstration elsewhere, notably by the traveling chemical "show" of the Museum of the Franklin Institute of Philadelphia. It seems wise to suggest to teachers of chemistry generally the use of such a demonstration and to make easily available the necessary directions and precautions.

In this experiment three kinds of fabric (usually sewed together) are put into a dye bath, dyed for a short while, and then taken out of the bath red, white, and blue. Various other color combinations are possible, but this seems to be the most popular one. No complicated apparatus is required, the materials are easily available, and the time needed is well within usual lecture period requirements. After the water is hot, the procedure takes less than five minutes. This amount of time will produce shades which are deep enough if the fabrics are displayed wet. All of the materials may be secured locally except the dyes; two specific sources of these that we have found satisfactory are suggested below.

For the fabrics we use a pure dye crepe silk, a viscose rayon crepe, and a cellulose acetate taffeta, purchased in a local department store. If not available locally, they can be purchased through one of the larger mail order houses. Sometimes acetate rayon sold as such is a mixture of acetate and viscose rayon; the heavy taffetas are usually pure acetate fiber. In any event it is wise to test the fabrics beforehand. The pieces demonstrated are about ten inches square, with the acetate sewed between the rayon and the silk.

In our procedure, we use a rayon, or direct cotton blue for the rayon, a silk scarlet dye for the silk, and leave the acetate undyed. For the rayon we use Diamine Sky Blue FF (Colour Index No. 518)[2], and for the silk, a special dye, Silk Scarlet 3B. This latter dye is manufactured only by the Althouse Chemical Company of Reading, Pennsylvania. Both dyes may be purchased directly from them. We have found these two dyes to be the most satisfactory, and to be the most nearly "fool-proof." With an alkaline bath, and sodium sulfate as the salting out agent, neither of these dyes will stain the cellulose acetate fibers at all. They come out perfectly white.

It is necessary to use soap or some other surface active agent. This not only hastens the dyeing process, but also helps to remove a certain amount of the finishing materials that may be found on the fabrics as purchased. Some of the newer surface active agents on the market give excellent results. We have used the commercial product "Dreft" with much success. Ordinary soap powders, such as "Rinso," "Chipso," and so forth, work very well. It is also possible to get fairly good results by simply using sodium carbonate to make the bath alkaline. Where extreme hardness of the water is experienced, it is wise to use distilled water.

The specific directions for a typical experiment, using the Althouse dyes, are given here. In all cases percentages given always mean percentage by weight of the materials dyed. It is therefore necessary to weigh the fabrics beforehand.

Two per cent. Diamine Sky Blue FF
Two per cent. Althouse Silk Scarlet 3B
Five per cent. soap flakes
Fifteen per cent. sodium sulfate, anhydrous
20:1 bath ratio

We use pieces of fabric about ten inches square. In one case this amount of rayon weighed six grams, cellulose acetate six grams, and silk five grams. For these quantities the volume of the dye bath is 340–350 ml. The water is brought to a temperature of 85° C. and 0.12 g. of Diamine Sky Blue FF, 0.10 g. of Silk

[1] Presented before the Division of Chemical Education at the ninety-seventh meeting of the A. C. S., Baltimore, Maryland, April 6, 1939. The procedure described in this paper was demonstrated before the Division.

[2] ROWE, *Editor*, "Colour index," The Society of Dyers and Colourists, Bradford, Yorkshire, England, 1924.

Scarlet 3B, and 0.85 g. soap flakes added and completely dissolved. The fabrics are then introduced and constantly agitated. Next, 2.5 g. of anhydrous sodium sulfate are added, either in the solid form or in concentrated solution. The dyes go on to the fibers very quickly after this; as soon as the shades become deep enough, the fabrics are taken from the bath, rinsed quickly once or twice, and then displayed.

We have also used successfully two dyes furnished by the du Pont Company. The dyes they suggest are just the reverse of those named above, a blue dye for the silk, "Pontacyl" Brilliant Blue 6B, and a red dye for the rayon, "Pontamine" Fast Scarlet 4BA, Colour Index No. 326. They may be secured from the E. I. du Pont de Nemours Company, Wilmington, Delaware. The quantities necessary are as follows.

One per cent. soap flakes
One per cent. soda ash
Three per cent. "Pontamine" Fast Scarlet 4BA
Two per cent. "Pontacyl" Brilliant Blue 6B
Twenty per cent. sodium chloride
40:1 bath ratio

The procedure is the same as with the other dyes; it is necessary here to keep pretty close to these percentages of materials to get good results, particularly for the soap and soda ash.

The experiment as described is almost "failure-proof." The percentages given, particularly for the dyes suggested, may be varied considerably. If necessary, extra dyestuff, or salt, may be added during the course of the demonstration, if the quantities first used do not produce satisfactory shades. In fact the quantities of materials suggested are more than needed for satisfactory dyeing, but it is often necessary in lecture demonstration to use a more or less "sloppimetric" method in order to get the essential speed. There are several precautions necessary to get even dyeing, the most important of which is to agitate or "work" the goods continually during the dyeing operation. If a temperature of 85° C. is exceeded, the cellulose acetate fabric might be damaged, with resulting loss of luster. It is easier to make up solutions of the dyes beforehand, and measure the quantities volumetrically. In the demonstration performed before the Division of Chemical Education at Baltimore, the quantities of all materials were simply estimated and added in the solid form. This can be done with a little experience.

Other variations of the experiment are possible. In one case we made a very close approximation of the United States flag. This was made by sewing together a field of rayon, and alternate strips of silk and cellulose acetate. We also point out in the demonstration that these dyes may be used as a test for the various kinds of fibers. This can be most strikingly shown with fabrics made of two or more kinds of fibers. Other fibers may be dyed: cotton and rayon will dye the same, and silk and wool the same. The experiment not only demonstrates the specific affinity of the dyestuffs for the different fibers, but it also shows the "salting out" effect. Other variations of the experiment will suggest themselves.

We have also adapted the experiment for the use of students in the laboratory. We issue two-inch squares of the three kinds of material, and make up stock solutions of the dyes, soap, and salt. A slightly higher bath ratio, 40:1, is used. The students weigh the cloth and calculate the necessary amounts of materials to use. The time of dyeing is increased to give deeper shades, as the students dry the samples and keep them. With small pieces of cloth, the expenditure for large classes is not prohibitive. The amount of dyestuff needed is not large, and the dyes suggested are not expensive when bought in one pound lots.

In closing, I should like to acknowledge the valuable assistance given by Mr. Harold C. Gift, of the Althouse Chemical Company, and Mr. A. G. Bruinier, Jr., of the E. I. du Pont de Nemours and Company, who assisted materially in the development of this experiment.

LABORATORY SPACE *for* CHEMICAL MICROSCOPY[1]

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Many instructors who see the advantages of chemical microscopy cannot find a suitable space in their crowded buildings for this type of laboratory. The purpose of this article is to show how this problem was solved in one instance and to suggest like possibilities to other teachers. The ordinary chemical laboratory tables are unsuited for this work for the student cannot sit or stand in front of them in a comfortable position and look through a microscope. After considering all possible locations a three-foot strip across the rear of a recitation room was selected and desks were designed combining comfort for the student with the necessities of the location. The details of these desks are described.

[1] Presented before the Division of Microchemistry at the ninety-eighth meeting of the A. C. S., Boston, Mass., September 14, 1939.

FOR five years a course of chemical microscopy was given at the University of Maine in the physical chemistry laboratory during mornings when this was not being used for its designed course. The tables in this laboratory were thirty-six inches high

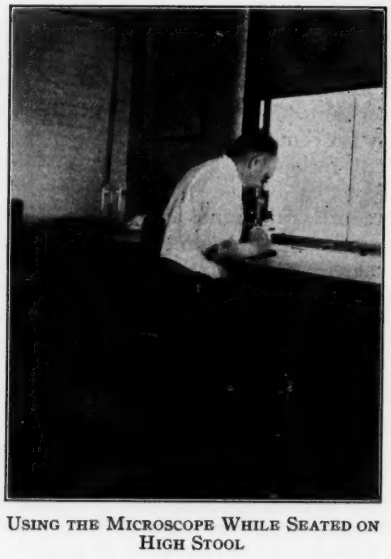
USING THE MICROSCOPE WHILE STANDING

with the usual straight front. The positions required for observation through a microscope were most uncomfortable. The straight front obliged a person sitting on a stool to spread his knees far apart or to sit sideways so that he might get close to the microscope. When standing the average person had to stoop to get his eye at the eye-point of the ocular, and this was tiring. In addition only half the natural light was furnished by a north window, the other by an east window with its consequent glare in the mornings. And the sills of these windows were so high that the whole field of a microscope placed directly in front of a window could not be illuminated. The other laboratory tables were so situated that their use was impossible.

As in most chemical laboratories, there were no unused rooms in the building, and search was made for suitable space that could be used without interfering too much with its primary purpose. The selected location was the rear of a recitation room. Fortunately, this was a north wall and had two windows in its twenty-three feet. By removing the last row of chairs, tables suitable for microscopy could be installed if they were placed parallel to the wall. This change would, of course, reduce the capacity of the room for recitations, but it was rarely used to full capacity for this purpose. The microscopy laboratory could be scheduled for afternoons, while the room was used for recitations only in the mornings.

The bottoms of the windows were forty-five inches from the floor and the previous experience had shown that with a microscope set twenty-four inches from the wall at a height of thirty-six inches the mirror could not reflect light from the sky into the microscope without the edge of the stage or the bottom of the window occupying part of the field of view. The table height of twenty-seven inches recommended by Chamot[2] and Cool[3] would, of course, be still worse. It was decided, therefore, to raise the top of the table almost to the level of the bottom of the window, to raise the height of the chair seat the same amount and to include a resting place for the feet twenty-seven inches below the table top.

The accompanying sketch shows the design of the working space for one student. Four of these tables



USING THE MICROSCOPE WHILE SEATED ON HIGH STOOL

were built by a local concern and together with an alberene sink occupied the available wall length of twenty-three feet. As recommended by Chamot a semi-oval section (twenty-two inches wide and eight inches deep in the middle) was cut out of the table top to enable the student to rest his elbows on the desk while using the microscope and also to pivot somewhat to work with different apparatus. This was placed a little to the left of the center in order to make the drawers on the right as large as possible while still leaving room for the microscope case in the cupboard on the left. The cupboard was placed on the left and the drawers on the right because a student has to reach many times in a laboratory period for various small pieces of apparatus, but usually only once for his microscope. This also allows more desk-top space for work

[2] CHAMOT, "Laboratory construction and equipment," National Research Council Committee Report, The Chemical Foundation, Inc., New York City, **1930,** p. 235.

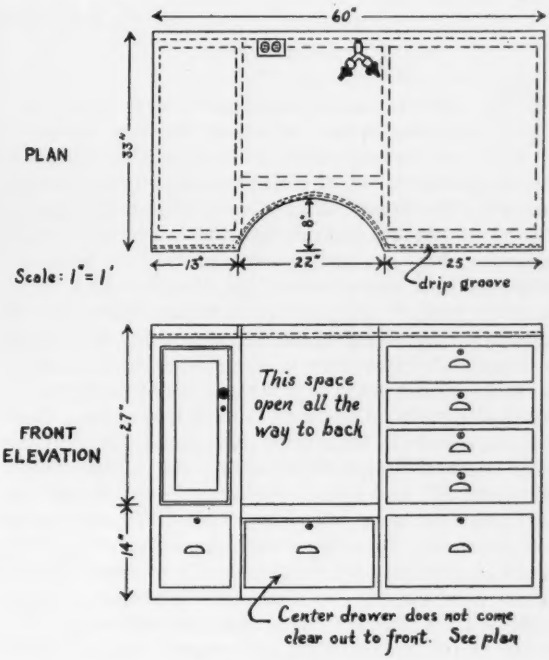
[3] COOL, "A small laboratory for chemical microscopy," J. CHEM. EDUC., **9,** 2084–9 (1932).

with his right than with his left hand. The four top drawers are assigned separately to students in different laboratory sections who use the microscope cupboard in common. The large drawers at the bottom, being unhandy for the student to use while seated and also

VIEW OF MICROSCOPY TABLES AT REAR OF RECITATION ROOM

not needed for this purpose, are used by the instructor for storage of special equipment. Setting the center drawer back eight inches allows the stool to be pulled up into the opening so that the student may sit comfortably while taking advantage of the "cut-out" place. Large pieces of equipment, such as a microbalance, euscope and comparison microscope, are stored in a cupboard in the lecture table in the room. The stools, which are of a standard commercial pattern, are adjustable to a height of thirty-three inches. Sitting on the stool with his feet in the space above the center drawer, the student is in the same position as if he were on a chair of ordinary height at a desk twenty-seven inches high. The same result would have been attained by building a platform fourteen inches high, but this would have had to extend about three feet in front of the desk to allow for the stool being pushed back and would have taken additional space from the room for recitation purposes. There would also have been some danger of accidents.

An unexpected result was the ease of working while standing up at the desk. The forty-one inch height brings notebook, burner, reagent block, microscope, and other equipment to a more comfortable position for observation than the usual thirty-six inch desk. Even relatively short students find this comfortable. Thus,



MICROSCOPY TABLE

the student has two possible positions which he can assume alternatively as he wishes.

The tables have been in use now for three years and have been found entirely satisfactory. This experience shows how little space is needed for a microscopy laboratory and how it may be found in a crowded chemistry building.

TWO NEW AWARDS ANNOUNCED BY SCHOLARSHIP COMMITTEE

The Federation of Paint and Varnish Production Clubs is offering two prizes of one hundred fifty dollars ($150.00) each for the best papers on paint and varnish subjects. The conditions of the contest are as follows. (1) There will be two prizes of $150.00 each; one for undergraduate students and one for graduate students. (2) The papers should be on some subject of interest or importance to the paint and varnish industry and may be on either practical problems of the industry or on research problems. (3) The contest will be open to undergraduate students and graduate students of any college, university, or technical school in the United States, Canada, or England. (4) Both prizes will be awarded no matter how many papers are sent in and no matter what the committee considers the quality of the papers. (If there should be no paper sent in by one of the classes of students, no award will be made for that class.) (5) Papers should be in the hands of the Federation Committee by June 30, 1941. (6) The Federation Committee will be the judges. (7) The Federation retains the right to publish any paper submitted whether it receives an award or not. Papers not published will be returned if the author so desires. (8) In publishing papers recognition will be given to the author and to the institution at which he is a student. (9) Papers should be typewritten. (10) At least two copies of the paper must be submitted. (11) Papers previously published will not be eligible for the prize. (12) The prize will be given to the paper, and if there is more than one author, the authors should make their own arrangements in regard to dividing the prize money. (13) The prizes will be awarded at the Annual Convention of the Federation to be held in October, 1941.

KENNETH J. HOWE, *Chairman*,
Scholarship Committee,
Federation of Paint and Varnish Products Clubs
5-48—46th Road, Long Island City, New York

QUANTITATIVE ANALYSIS *and the* THEORY *of* MEASUREMENT

FRANK H. HURLEY

The Rice Institute, Houston, Texas

THE importance of measurement is so great to a science that it can be argued whether a science without measurement is a science at all. The rise of chemistry out of alchemy is largely due to the fact that the purely descriptive material of alchemy was translated into precise mathematical terms through measurement; or, as Ida Freund said, "Chemistry only took rank as a science when it made quantitative work its basis." The nature of measurement and of calculation involving measured quantities is of such fundamental importance to the science that a failure to direct the attention of a student of chemistry to the study of measurement and calculation is to keep from him the essence of the science itself, and to deprive him of a basis of judgment regarding the measurements which he will make if he continues in chemistry, and also those of other scientists which will come before him for evaluation. There are many interesting philosophical ramifications to the theory of measurement which bear directly on the validity of the scientific method itself, but if it were only this which gave the study of measurement its importance, the pursuit of such studies would be of doubtful value for most chemists. The fact is, however, that a study of measurement is of considerable practical importance, and a chemist with some knowledge of the subject is often in a position to save himself both time and money in actual experimental work by designing experiments to fit his needs accurately, instead of proceeding blindly in the hope that if enough measurements are made or if only the most expensive equipment is used, everything will turn out all right.

The most logical and appropriate place for the study of measurement and calculation in the chemistry curriculum is in quantitative analysis, for it is at this stage that the student is, or should be, introduced to measuring instruments worthy of the name, and is taught to use them in an exact fashion, which is usually very different from the hurried and sometimes slipshod fashion which characterizes most of the measurements of the freshman or high-school course. Moreover, in quantitative analysis the object of the work is generally to make measurements for their own sake, without any special emphasis on their application to some theory or set of conditions which might be under investigation. Under these circumstances it would seem that the course in analysis offers the best opportunity for a study of the so-called "calculus of observations."

Unfortunately, of the many textbooks on quantitative analysis which are in common use, very few have recognized this opportunity by the inclusion of adequate discussions of the problem of measurement There are two noteworthy exceptions to this generalization, namely the texts of Fales (*2*) and of Kolthoff and Sandell (*3*), both of which contain separate chapters dealing with the subject. In the main, however, the topic is treated by a few very brief statements or rules with no clue to their basis except (in the better books) a footnote referring to more complete treatments. In some texts even the inadequate discussion is confused or erroneous. For example, the following quotations taken from the 1929 edition of a well-known text contain statements which are totally incorrect.

"Thus suppose that the mean of four runs such as buret readings is 30.255 cc. and that the average deviation of a single reading is 0.005; then $0.005/\sqrt{4} = 0.0025$ is the probable error [*sic*] in the above buret readings. The result is then expressed as 30.255 ± 0.0025 and means that an error of 0.0025 cc. is introduced in the buret reading.

"It is to be noted that closely agreeing checks are not a necessary indication of a good precision because a large error, of the same kind, may have been introduced in all the determinations."

No references to sources of correct information accompany these erroneous statements.

No one would expect a chemist who is not specifically interested in precise measurements to have a complete knowledge of the mathematical theory of statistics and probability, but it is not unreasonable to expect him to understand how measurement and calculation are related to probability theory, to know exactly what is meant by expressions such as "probable error" and "standard deviation," and, most especially, to understand the precise significance of his own measurements. Benedetti-Pichler (*1*) has recently drawn attention to the importance and value of statistics in quantitative analysis in an interesting paper with which all students of analysis might be expected to be familiar.

The nature and scope of a discussion of measurement and calculation to be included in a course in quantitative analysis will, of course, be subject to limitations depending on the time available, but the following outline may serve as the basis of such a discussion.

I. Experimental Errors
   (*A*) Indeterminate Errors

(1) Gauss' Error Curve
(a) The "best representative value"
(2) The arithmetical mean and the number of measurements
(a) Indeterminate error of a single observation
1. The average deviation
2. The standard deviation
3. The probable error
(b) Indeterminate error of the mean
(c) The practical number of measurements
(3) The trustworthiness of individual measurement
(a) Rejection of measurements
(B) Determinate Errors
(1) Classification
(C) Absolute and Relative Error

II. Accuracy and Precision
(A) Definitions
(B) Determination of Precision
(C) Determination of Accuracy
(1) The problem of the "true value"
(D) Accuracy and Precision in Quantitative Analysis

III. Significant Figures
(A) Definition and Usages
(1) The purpose of significant figures
(B) Semi-exponential Notation
(C) Pure Numbers

IV. Error and Calculation
(A) Propagation of Error
(1) Addition and subtraction
(2) Multiplication and division
(B) Rules of Computation
(C) Methods of Computation
(1) Slide rule
(2) Logarithms
(3) Shortened arithmetic

There are several sources, in addition to those already mentioned, from which such a discussion can be drawn (*4*, *5*, *6a*), but it may not be amiss to note here, certain points on which there is some disagreement or difficulty. At the outset it is necessary to define determinate and indeterminate errors, and the following definitions of these terms are suggested.

Indeterminate errors are errors of measurement which have signs and magnitudes determined solely by chance, and therefore cannot be controlled by the observer.

Determinate errors are errors of measurement which have signs and magnitudes determined by laws relating them to their causes, and therefore can be controlled or evaluated, provided the laws and causes can be discovered.

It is believed that these definitions are more accurate and informative than many which have previously been given. The terms "vectorial" and "non-vectorial" are very satisfactory substitutes for "determinate" and "indeterminate," since in many instances it is easier to "determine" the indeterminate error than the determinate.

Perhaps the most difficult part of the discussion of measurement is that relating to the trustworthiness of individual measurements. There are many criteria for the rejection of aberrant observations and it is difficult, if not impossible, to adopt any one which will be universally applicable and which will actually effect the rejection of untrustworthy results. No matter what criterion is adopted, the rejection must finally be subjected to the scrutiny of common sense, a criterion which is probably no worse (nor any better) than the mathematical formulas. The convention most frequently adopted in quantitative analysis (and the one recommended by Benedetti-Pichler) is the arbitrary rejection of a measurement with a deviation greater than four times the average deviation. This is a variant of Wright's criterion (*6b*), based on the probable error. It is worth mentioning that the figure given in most analysis texts for the probability on which this rule is based is incorrect. The figure usually given, 993/1000, refers to four times the probable error instead of the average deviation. The correct probability is 999/1000 (*6c*).

The recommendation that relative errors in quantitative analysis be given in parts per thousand rather than per cent. to avoid confusion with analytical results, which are usually expressed in per cent., has been pretty widely adopted. The use of the symbol, ‰, for parts per thousand (*1*) also merits adoption, and the terms "per mil" and "permillage error" might also be convenient.

The subject of significant figures is one which most students find rather confusing and the source of the confusion is not hard to find. They are given a set of rules and conventions which are stated to cover the subject and then must reconcile these with flagrant violations on the part of the instructor and the textbook. The important point about significant figures, and the point which is frequently omitted in the hurry to get to the rules, is that the purpose of giving a measurement its correct number of significant figures is to indicate its approximate precision. Thus, it is quite impossible to write a measurement with its correct number of figures unless there is some knowledge as to its reproducibility. To relate significant figures to the estimations involved in reading a measuring instrument is one thing, and to relate them to the real reproducibility of the measurement is another, a distinction carefully pointed out by Benedetti-Pichler.

The rules for the number of significant figures to be used in the expression of a measured quantity differ rather widely among authors. If the mean figure 21.23 per cent. is obtained as the result of an analysis, most writers on the mathematical theory of measurements would say that it indicates that the correct value lies between 21.225 per cent. and 21.235 per cent., or has a precision of ±0.005 unit. Others would say that the indicated precision is ±0.01 unit. Most

chemists do not actually use such a narrow criterion and would feel perfectly correct in writing the figure as given if it were obtained as the mean of the two measurements 21.20 per cent. and 21.26 per cent. There is general agreement that in writing a number representing a measurement, all the numbers written should be "certain" except the last, which is the first "doubtful" figure. The source of the conflicting conventions is in this last figure, and some convention as to how "doubtful" the last figure may be must be adopted before general agreement can be obtained. Perhaps the most satisfactory way to treat the last significant figure is to give a rough indication of its doubtfulness by the use of subscripts. Using this convention, a measurement written as 21.23 would indicate a precision (average deviation of a single observation) of ± 0.01 unit. If the average deviation is greater than this, the number would be written as 21.2_3. The adoption of this convention reduces all rules for the use of significant figures to the following. In writing a number which represents a measured quantity, use the number of significant figures which comes nearest to expressing the real precision of the measurement, using a subscript if the last figure is less precise than ± 1.

In making calculations with numbers representing measurements, it is unusual to find a student who regards these figures other than as pure numbers. A study of the way in which errors of measurement are propagated in the ordinary arithmetical operations is not ordinarily a part of his previous mathematical training, and a discussion of this topic should be included in the course in quantitative analysis. The knowledge of the way a final answer is affected by the errors of its antecedent measurements is important in the consideration of a completed analytical result, but an even more important use of such knowledge is its application to projected measurements. Unless a student has some grounding in the theory of propagation of error in calculation, it will be difficult, if not impossible, for him to analyze critically a proposed measurement and to make arrangements to perform it by methods which will satisfy his requirements of accuracy and precision. This is especially true of analytical determinations which are obtained by computation from several antecedents. Most quantitative analyses are of this character, and in every analysis a preliminary calculation is required to decide what size sample of the material to be analyzed should be taken to fit the conditions of the analysis. In most textbooks these calculations have already been performed for the student, and the directions for a determination usually begin, "Weigh out 0.5 g. of ...." This is very convenient for the instructor, but it is apt to lead the student to believe that 0.5 g. is the proper size sample to be used no matter how much or how little of the constituent being determined is present. The failure to indicate how the sample sizes, the quantities of reagents, concentrations of solutions, and so forth, were decided upon is a gap in the instruction which should not be left open. Decisions about these quantities are always partially, and sometimes wholly, based on the propagation of experimental error in calculation. A student who has been shown how these decisions are made will be in a position to make them for himself when the need arises.

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(3) KOLTHOFF AND SANDELL, "Textbook of quantitative inorganic analysis," The Macmillan Co., New York City, **1937**, Chap. XV, pp. 250–78.

(4) MELLOR, "Higher mathematics for students of chemistry and physics," Longmans, Green and Co., London, **1916**, Chap. IX, pp. 498–566.

(5) PALMER, "The theory of measurements," The McGraw-Hill Book Co., Inc., New York City, **1912**, 248 pp.

(6) (a) TUTTLE AND SATTERLY, "The theory of measurements," Longmans, Green and Co., London, **1925**, 333 pp.
(b) *Ibid.*, p. 212.
(c) *Ibid.*, p. 194.

CORRESPONDENCE

"A HIGH-SCHOOL COURSE IN CHEMISTRY WHICH DOES NOT LEAD TO REPETITION IN COLLEGE"

To the Editor

DEAR SIR:

In your January number appears an article by P. M. Glasoe of St. Olaf College. It is apparent to me that the writer of this article is not a teacher of high-school chemistry, at least in a typical situation. Of course, the folk in colleges are entitled to a certain amount of grandstand quarterbacking, but the contents of this particular article appear, I regret to state, as being rather distant from the truth in many points.

Even the first sentence is misleading. Freshmen in our more progressive larger colleges are, contrary to

Mr. Glasoe's statement, admitted to advanced work in chemistry. If a specific example is required, I will refer to Princeton University, where those taking freshman chemistry are divided into three groups. If there are some colleges which have not yet realized the virtue of a plan such as this, I venture to state that the fault lies with them, and not the high-school chemistry course: and that they will eventually succumb, one way or the other.

Mr. Glasoe's second premise is equally to be criticized. The high-school course, although it deals with general topics similar to those found in most college books, stands on its own feet, and does not attempt to copy any college course. Here I am defending particularly those numerous schools where we have the high-school chemistry course varied so as to meet the needs of both college preparatory and non-college preparatory groups. Smaller schools, of course, cannot do this, and are to be pitied rather than condemned. A hopeful view of this latter problem is found in the recent tendency toward consolidation and creation of regional high schools.

That the enrolment in high-school chemistry has decreased from 9.62 per cent. to 7.31 per cent. of the school does not worry me so much. It merely reminds me of the fact that there are three kinds of lies—lies, damned lies, and statistics. Forty-odd years ago the high schools were small, offered limited curricula, and the average pupil had a much higher I. Q. than today. With the wealth of new courses which have been added during the last few decades, in the field of social studies and commercial subjects, large numbers of pupils have naturally been displaced from other subjects. And this is without great regret, for we have large numbers of pupils in our schools today who are mentally incapable of anything that might by the severest stretch of the imagination be called chemistry.

As for the physics, I regret that space does not permit discussion of the statistics here. But I will digress to the extent of stating my belief that the St. Cloud case cited by Mr. Glasoe is hardly typical. Without detracting from the praise which Mr. Nelson of that school undoubtedly deserves, it seems to me that a course in which enrolment increases from thirty to two hundred eighty must have been something awful in the beginning, and that there were probably other factors, such as a different teacher personality, or a different attitude on the part of the school administration, which contributed to the increase.

Returning to the chemistry, we get to the root of Mr. Glasoe's intentions when he unfolds for us a NEW PROCEDURE. As I study this procedure, it becomes more apparent that Mr. Glasoe's "New Course in Chemistry" is not a chemistry course founded in general science. It is general science itself. It is not chemistry.

The modern high-school student of even less than average intelligence feels insulted if he is offered something which pretends to be chemistry, but is really an embellished general science course. Here I would like to pose Mr. Glasoe a question. Is there any more justification for setting up a chemistry course which is just like a general science course that a student has had two or three years before, than there is for having a college chemistry course that is just like a high-school chemistry course?

Our high-school students want chemistry that is chemistry. Is this kind of chemistry popular? It is, if it is taught humanely. To be humane, it does not have to be too easy, but it has to be challenging enough so as to give the student a feeling of accomplishment when he has completed the course. The student should know what chemistry really is. Is it fair to deceive him and lure him into some chemical vocation, because he has done well in a chemistry course that is not chemistry?

My students are not bored with the real chemistry. About ninety-five per cent. of those students who are eligible to take it, do so. And it is not a required subject.

WILLIAM E. PRICE

BLOOMFIELD HIGH SCHOOL
BLOOMFIELD, NEW JERSEY

To the Editor

DEAR SIR:

Thank you for permitting me to see Professor Price's letter. Far be it from me to enter into any wordy argument about the subject matter of my paper in the January issue of the JOURNAL OF CHEMICAL EDUCATION. No sooner had the JOURN L appeared than I began to get letters and cards making comments. One said, ". . . . too sadly true! The whole subject is so vital that I would appreciate receiving a reprint; better still three reprints. I would like to put them in the hands of a few responsible persons who might be able to start something along this line. Most gratefully yours." This letter was from a man at the head of a large eastern college chemistry department.

The chairman of the physical science department of a large New York high school says, "May I express my sincere appreciation for the contribution, and so forth. Would like a syllabus if available."

Then, from the chemistry head of the chemistry department in another large New York high school comes a letter, three solid pages, single spaced. This man has taught chemistry for more than fifteen years and is full of the subject. "Please let me say at the outset that I say 'Amen' to your idea." I gather that he, and many more with him, would like to see "something started," but who is to hang the bell on the cat? That's the question.

Then as to Mr. Price's objections. I am not a high-school teacher—I have taught chemistry in college for almost forty years. I have always fought the battle of the high schools against unfair criticisms from college and university professors; I published a paper in the JOURNAL in an attempt to measure the "carry over" of high-school chemistry into college. I have insisted that when both those with and without high-school

chemistry are put into the same course in college it is not a case of those without high-school chemistry *catching up*, it is a plain case of *keeping those back* who entered with high-school chemistry. I am quite certain that I was the first one, out here anyway, who separated the two groups and treated those who had had high-school chemistry as if their one hundred eighty hours of high-school chemistry had meant something to them. I have never regretted it.

What I contend is that the college first-year course does not stand on its own feet—it stands on the toes of the high-school course. The high-school course does not need to copy a college course; the textbook writers have seen to that and so successful has been their effort that the books are *all but identical*.

As for the statistics, they are not lies at all—they are too cruelly and graphically true. Chemistry has *stood still* for forty years—something must be the matter.

I insist that my suggestion is not only real chemistry, but realistic chemistry; a course that will teach the ninety-eight per cent. of our young people who do not go into scientific pursuits what chemistry is, what it does, and its glorious history. When a course in high-school chemistry or physics in your town makes it necessary for the salesmen and merchants of the community to *go to school* to study the articles of their trade so as to be prepared to meet the skilful scrutiny of the boys and girls of the homes, that comes near being a case of putting high-school science on the map. That's what happened in St. Cloud, Minnesota. Merchants and salesmen have had to study in self-defense to meet the intelligent questions and arguments of their prospective customers.

This idea that you are giving the class a substitute or that you are putting something over on them by teaching them what is useful, what they will never forget, instead of thousands of facts to be forgotten next year, is the old argument of fifty years ago which had to be fought out before chemistry was allowed in the curriculum at all.

The person who is not teaching high-school chemistry as a glorified general science is out of step by fifty years—chemistry is *the General Science:* it underlies every science—and that means it forms the basis of all life. Let us make high-school chemistry a Glorified General Science Course with a capital G.

It is interesting that several letters commending my article came from the bailiwick of the College Entrance Examination Board and the Regents of the State of New York.

P. M. GLASOE

ST. OLAF COLLEGE
NORTHFIELD, MINNESOTA

To the Editor

DEAR SIR:

I thoroughly enjoyed Professor Glasoe's article in the January issue on "A High-School Course in Chemistry Which Does Not Lead to Repetition in College." With most of his points I agreed heartily. However, in his suggestions for the new procedure, on page 14, I feel that his example of the sort of thing to teach in the high-school chemistry course was not well chosen—it is doubtful in my mind whether a detailed, lengthy study of the Weather Bureau, high and low pressure areas, trade winds, tornadoes, whirlwinds, and so forth, is appropriate for the chemistry course. Since no chemistry is involved in that subject, it should be given in general science, physics, or meteorology (geography), and a better example for Professor Glasoe's purpose would have been something dealing with chemistry and chemical changes.

GRANT W. SMITH

THE UNIVERSITY OF KANSAS CITY
KANSAS CITY, MISSOURI

"MNEMONIC DEVICES IN CHEMISTRY"

To the Editor

DEAR SIR:

I read with interest Lieutenant Bermingham's article, "Mnemonic Devices in Chemistry" (J. CHEM. EDUC., **16**, 516 (1939)). I would like to call your attention to another interesting mnemonic device which I have found quite useful. It is, "Oh my, such good apple pie, sweet as sugar." The initial letters of these words comprise in order the initial letters of the names of the saturated aliphatic dibasic acids. This device is not original with me, but was passed on to me several years ago by a student from the Massachusetts Institute of Technology.

HOWARD M. TEETER

UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

"FLUORSPAR—ITS CHEMICAL AND INDUSTRIAL APPLICATIONS"

To the Editor

DEAR SIR:

In my article, "Fluorspar—Its Chemical and Industrial Applications," in the April issue of the JOURNAL I failed to give credit to Martin Schwerin for the ideas embodied in the following sentences.

"The deposit operated by Victory Fluorspar Mining Company is a replacement of the limestone, the banding of the ore, typically illustrated in Figure 3, being a relict structure due to physical and chemical differences in the layers of the original limestone resulting from seasonal changes while it was being laid down. The comb structure of pure bands is due to a decrease of volume, the CaF_2 molecule being more dense than the $CaCO_3$ molecule which is replaced."

The geology of the deposit was covered by him in an article entitled "An Unusual Fluorspar Deposit" published in the *Engineering and Mining Journal*, for September, 1928.

LENHER SCHWERIN

VICTORY FLUORSPAR MINING COMPANY
ELIZABETHTOWN, ILLINOIS

OBJECTIVE TESTS IN ORGANIC CHEMISTRY

The 1940–1941 Series of the Coöperative Objective Tests in Organic Chemistry are now in the process of preparation. It is believed that the present series will meet the need of the average instructor of organic chemistry somewhat better than any of the tests of this series thus far prepared. It is hoped, furthermore, that those who elect to use these tests during the coming school year will coöperate with us to the extent that this series may be standardized and the validity of each item determined.

One page is devoted to each of twenty-six topic examinations in organic chemistry, and three pages each to the final examinations for the first and second semesters, making a total of thirty-two mimeographed pages to a set. These sets are available to instructors and graduate students or research workers in lots of five or more at twenty cents each. Single sets are thirty-five cents. Those using these tests in their classes will be provided with a key for convenience in grading.

Anyone who is interested in examining or using the 1940–1941 Series of Coöperative Objective Tests in Organic Chemistry may place his order with Ed. F. Degering, Chairman, Coöperative Objective Tests in Organic Chemistry, Purdue University, Lafayette, Indiana.

ED. F. DEGERING

PURDUE UNIVERSITY
LAFAYETTE, INDIANA

"THE EFFECT OF THE NATURE OF THE COURSE ON ACHIEVEMENT IN FIRST-YEAR COLLEGE CHEMISTRY"

To the Editor

DEAR SIR:

Clark might be able to philosophize upon the so-called "conclusion—inevitable" that he makes in the article entitled, "The Effect of the Nature of the Course on Achievement in First-Year College Chemistry,"[1] but no statistician or scientist would allow him to base his conclusions upon the numerical gymnastics that he describes. Of course, it is possible that the experimenter may have made many other computations without bothering to record them in his paper. Certain additional data could certainly prove useful, but this critic will naturally have to assume that all of Clark's work is described in the report. Little does Clark apparently realize how correct he actually is when he says, "Perhaps the reader should be cautioned against indiscriminately applying the above conclusions to other groups of students."

(1) Clark attempts to compare the gains made by students in the elementary group and the advanced group by determining their "average gain". He obtains this gain by "end-test percentile minus pre-test percentile." By chance, the particular groups with which he was dealing (those having had high-school chemistry credit) actually increased their percentile ranks, thereby allowing him to obtain positive numbers rather than negative ones. Percentile ranks are similar to rank order in which it is easy to understand that a class of seventy-five must have seventy-five rank orders represented both in the pre-test and in the end-test. The various changes both plus and minus that occur must always become equal to zero algebraically. A person holding his own must actually be gaining in true score and achievement if the class as a whole is learning anything. If a group, as was the case here, actually gains in rank order or percentile, it merely means that they are somewhat more select in their rate of increase than the others in that *same* group. Clark compares these rates of gains with the rates of gains of another group that apparently has not been equated in any way. These figures are meaningless and misleading.

(2) Clark finds a correlation of 0.88 between the pre-test and end-test percentiles for the control group (elementary chemistry). In the first place, percentiles represent a rectilinear distribution rather than a frequency distribution which might be more similar to the normal curve. Equations for computing correlation are not designed for rectilinear distributions and therefore the data are less meaningful than might be supposed.

(3) However, after finding this correlation of 0.88, Clark sets up a regression (*for this elementary group*) and gives it as

$$X_1 = 0.98\,X_2 + 17.12$$

With this, he can predict the end-test ranks from those on the pre-test. Accordingly, "end-test percentiles were then predicted for all members of the control group and a correlation of 0.88 was actually found between the predicted and the earned values." All Clark seems to have proved by this useless manipulation is that his arithmetic has apparently been correct both times and that the old truth, things equal to the same thing are equal to each other, is still as true as ever.

(4) "By means of this same regression equation," Clark then predicted the end-test percentiles for the students in the advanced group. The real meaning of

[1] CLARK, "The effect of the nature of the course on achievement in first-year college chemistry," J. CHEM. EDUC., **16**, 510–11 (Nov., 1939).

the regression equation implies that for that group, and for that particular course, there is a certain relationship between pre-test percentiles and end-test percentiles. Using that same regression equation on the data from another class, one should certainly not expect to predict *their* final-test scores. The only thing that Clark might have presumed, but apparently didn't, is that this would indicate the ranks that the students in the advanced class might have attained if they had, instead, been in the elementary class.

(5) Correct use of the regression equation technic for comparing data makes it entirely unnecessary to pair the students from the two groups. However, Clark has paired thirty-two students in the elementary group with thirty-two in the advanced group. He apparently paired them on the predicted end-test score for he says "both members of a given pair had the same predicted end-test percentile." It will be remembered from the previous paragraph that the same regression equation was used for both groups and hence if the predicted scores were the basis for pairing, he might just as well have used the pre-test percentiles of which they were directly a function. Again, Clark laboriously tests his own arithmetic by discovering that the "mean predicted end-test percentiles were exactly the same for the two groups, *i. e.*, 58.9 . . . ." He chose those which were equal, so it is little wonder that they actually are equal.

(6) After his job of pairing the individuals, he states that "within the limits of error of the experimental method employed, the members of Group C should have earned the same mean percentile on the end-test as the members of Group B except for the influencing factor of the course taken in college chemistry." He finds that the mean earned end-test percentile for the elementary group was 59.9 and that for the advanced group was 65.3. Again, let it be emphasized that one cannot compute the difference to be 5.4 percentile and attribute that this "difference is in favor of those students who took . . . . the course designed especially for them." The individuals were paired without any concept of the meaning of percentile ranking in the first place, for the actual achievement medians of the two groups had not been equated. Then, even though they had been equated and assuming that they had been matched correctly at the beginning of the experiment, the actual end-test percentile has no meaning unless these medians are equated again.

Clark concludes his article hoping "that this paper may also serve to remind chemistry teachers of the applications of the well-known experimental method to problems of an educational nature." This critic would like to conclude this paper with the hope that all those who are familiar with the same "well-known experimental method" refrain from using it in problems of this sort.

SHAILER A. PETERSON

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UNIVERSITY OF MINNESOTA
MINNEAPOLIS, MINNESOTA

To the Editor

DEAR SIR:

I am writing this letter concerning the criticisms of Peterson of my paper entitled, "The Effect of the Nature of the Course on Achievement in First-Year College Chemistry."[1]

His major criticisms seem to arise from a lack of understanding as to how I calculated the percentiles which my students made on the pre-test and on the end-test. He apparently assumes that the raw scores earned by the students were transmuted into percentiles by using norms established for each local group of students and for each of the two times the tests were given. This assumption is incorrect and seems unjustifiable in view of the fact that I cited a previous publication[2] of mine in which the source of the norms used was explained. However, I shall repeat it here.

For a given student, the pre-test and the end-test forms were exactly the same. However, not all students included in the study took the same form. They were all either "Iowa Placement Examination," New Series, Form X or "Iowa Placement Examination," Series C T_1, Revised A. The norms used were those developed by the Bureau of Educational Research and Service of the Extension Division of the University of Iowa, and the same norms were used in transmuting end-test scores as were used in transmuting pre-test scores. Hence the end-test and pre-test scores of all students were equated on the basis of Iowa percentile norms.

Due to the fact that not all of the students took the same form, raw scores could not be used. Since it seemed desirable to include more students in the study than reports on either form would permit, transmutation into percentiles and a combining of the groups were decided upon. This was done only after receiving the favorable advice of a representative of the psychology department of the State University of Iowa.

Using the gain which a student showed, then, in his percentile (end-test percentile minus pre-test percentile) would be equivalent, but not mathematically equal, to using the gain which he would have made on his raw scores. Certainly in this case Peterson's comment that "the various changes both plus and minus that occur must always become equal to zero algebraically" would be absolutely untrue. As a matter of fact, in reviewing my data, I find that the percentile of only about ten per cent. of all of the students (not just those paired) was less for the end-test than for the pre-test. This would be expected when the method which I used was employed. Peterson has just missed the point.

Peterson's comment about the application of the regression equation to the advanced group does not hold, in view of the fact that the equation was derived from

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[1] CLARK, "The effect of the nature of the course on achievement in first-year college chemistry," J. CHEM. EDUC., **16**, 510–11, (NOV., 1939).

[2] CLARK, "The effect of high-school chemistry on achievement in beginning college chemistry," *ibid.*, **15**, 285–9 (June, 1938).

the Iowa norms and not from local norms for each group.

The paper as I originally submitted it for publication did include a detailed statement of the method of converting raw scores into percentiles, but the editor asked me to condense it and I did so. In doing this, I do not think that I affected the value of the paper in view of my generous citation of other articles.

I do not mind Peterson's comments on my use of checks in certain portions of my study. No scientist need ever apologize for checking on his work (even on his arithmetic). The fact is that he should be criticized if he did not do so.

When I cautioned the reader against "indiscriminately applying the above conclusions to other groups of students" I fully realized the import of my words, although Peterson apparently does not give me credit for it.

My concluding remark, "It is hoped that this paper may also serve to remind chemistry teachers of the applications of the well-known experimental method to problems of an educational nature," is apparently badly misconstrued by Peterson. I had in mind the universally known general method which is well described by Crawford.[3]

"In its bare essentials, it consists of providing a situation where phenomena can be repeated and controlled, and then varying one element in the situation to see what variation in the results is thereby produced. This means the isolation of a single variable and the determination of its results when the other variables or elements in the situation are constant." I certainly did not refer to the specific technic which I used, although I do think that this particular technic of employing the experimental method might well be studied more carefully by certain teachers. Again according to Crawford[3] *the experimental method* "is recognized as probably the most essential instrument available in the quest for truth." *The* experimental method is certainly well known to all *scientists*.

I shall now leave it to the discriminating reader who may have read my paper and the correspondence which it has evoked to judge for himself whether I have truly used the experimental method and whether other chemistry teachers should be encouraged to try to apply this general method to their own educational problems.

PAUL E. CLARK

MUSKINGUM COLLEGE
NEW CONCORD, OHIO

[3] CRAWFORD, "The technique of research in education," The University of Southern California, Los Angeles, Calif., 1928, p. 29.

A CHEMISTRY CLASS CONSTRUCTS *a* LABORATORY APPARATUS

WALTER V. BURG

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Exercises that engage a class in the construction of apparatus for laboratory experiments can be arranged so as to constitute a valuable addition to the customary program for courses in elementary general chemistry.

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MOST of the laboratory manuals for elementary general chemistry contain rather comprehensive directions as to the setting up of apparatus for the various student experiments. Such an arrangement, although generally welcomed by the instructor as a decided help in his work, bears the danger that throughout the entire course the students may be kept from using their own ingenuity in combating even minor technical difficulties. This would be especially regrettable with regard to those students who are mainly interested in theoretical problems and to whom the chemistry course could offer a valuable opportunity for developing a more favorable attitude toward the practical side of things. As a means to avoid those disadvantages the author wishes to suggest adding to the laboratory program a few exercises that engage the class in a technical problem, such as the construction of an apparatus to be used by the students for their chemical experiments. Although exercises of this kind generally require more painstaking preparations than the customary laboratory experiments, their high educational value fully justifies the increased effort on the part of the instructor. This applies particularly to the selecting of the object, which has to be done with

more than the usual care in order to assure a sufficient degree of difficulty and at the same time enable the students to accomplish their task with a minimum of help.

In the following lines the successive steps are described by which the students of a first-year chemistry course—under the guidance of their instructor—carried out an exercise of the kind mentioned above. The exercise was given in the early part of the course after the chapter on oxygen had been concluded and the study of hydrogen had been started. The students had just learned of the various methods for preparing this element and were also familiar with its combustibility and the explosive character of its mixtures with oxygen or air. Now the study of hydrogen was to be continued, which made the use of a convenient gas generator very desirable. Thus the topic of the next exercise suggested itself. It was formulated as follows: to construct a small but efficient laboratory apparatus for the preparation of hydrogen.

At the outset the students were confronted with an important question; which of the methods for generating hydrogen should they choose for their purpose? Briefly the class reviewed the different possibilities. Neither the reaction between sodium and water nor the decomposition of steam by heated coke or iron was found to be suitable, the former on account of the hazards involved, the latter because of the complicated apparatus required. On the other hand, the interaction between certain metals and acids offered a harmless as well as convenient way of preparing the gas. Therefore, it was decided to design the generators for the use of this method. The reacting substances were selected by the instructor; they were zinc and sulfuric acid.

Now the students turned to their actual jobs, the construction of the generator. What kind of container would serve best as the reaction vessel for the two substances? The experiments with oxygen (preparation of the gas from potassium chlorate) suggested a test-tube supported by means of a clamp and a ring stand. However, as several students objected, there was no need in this case for such an arrangement since the reaction did not require application of heat. A flat-bottomed vessel that could be placed on the desk without a supporting device would be entirely sufficient. After briefly examining their stock of containers the students decided in favor of wide-mouthed bottles which combined a sturdy construction with a satisfactory capacity. The bottles were provided with one-hole rubber stoppers and delivery tubes.[1]

After each student had arranged his apparatus and connected it with a pneumatic trough, zinc and sulfuric acid were distributed by the instructor. Only small amounts of acid were given out in order to prevent the reaction from becoming too violent. The generators were charged, closed, and the escaping gas was collected in test-tubes over water. As was expected, the first portions of hydrogen were mixed with air and exploded slightly when ignited at a distant flame. After a while all air had been expelled from the generators, as was evidenced by the quiet combustion of the gas. In the meantime, however, the reaction between zinc and acid had slowed down perceptibly. What could be the cause of this change? The bottles were opened and their contents examined. The students found that there was still enough zinc but that most of the acid had been used up. It became clear that, in order to obtain a continuous evolution of gas, fresh acid had to be added at frequent intervals. But there a difficulty arose since each time the stoppers were lifted from the bottles, the hydrogen was again contaminated with air. The students saw that their construction had to be modified so as to permit the addition of acid without opening of the generators. Therefore, it was decided to replace the one-hole stoppers by two-hole stoppers, each carrying a delivery tube and a funnel[2] for introducing the acid. However, the new model proved quite unsatisfactory since the gas now escaped through the funnel and none of it passed to the pneumatic trough. After deliberating briefly the class found a workable solution. The stems of the funnels were connected with short glass tubes by means of rubber tubing and the funnels thus extended into the liquid at the bottom of the containers. Now the generators seemed to be perfect. As soon as the gas evolution slowed down, fresh acid was added through the funnels and the reaction sped up again.

Although most of the students appeared to be well satisfied with their models, a few of them voiced the opinion that the apparatus could be greatly improved by providing some device for regulating the gas flow. As the generators were now constructed, there was no means to shut off the steam of hydrogen when the gas was not needed. Several proposals were made and discussed. The one finally agreed upon was to cut the delivery tube into two parts and to join the latter by means of a short piece of rubber tubing that carried a screw clamp. The changes were quickly performed and their effectiveness tested. However, the result was not quite what had been expected. Each time the gas flow was stopped by operating the clamp, part of the acid rose in the stem of the funnel. The phenomenon was studied and soon explained. The hydrogen, being prevented from escaping through the delivery tube, developed a pressure and thus forced the liquid upward into the funnel. Several interesting observations were made by the class. Not all of the acid was driven out of the bottle; there was just enough left to touch the end of the stem. From time to time a large gas bubble rose in the latter and burst when reaching the surface of the liquid that had collected in the funnel. Again the explanation was simple: the acid left at the bottom of the container was still in contact with zinc and, therefore, the liberation of hydrogen continued. But the effect was not quite the same in the different apparatus. There were a few generators in which the

[1] Delivery tubes had already been used for the preparation of oxygen.

[2] The use of funnels was proposed by the students since they had not as yet worked with thistle-tubes.

stems of the funnels extended into the zinc itself, and here, as the students observed, the acid did not cover all of the metal and the evolution of gas was much slower. A lively discussion started which led to an important conclusion: if it were possible to extend the funnels below the zinc, all of the acid could be forced away from the metal and the reaction brought to a complete stop.

The class now entered upon the most interesting phase of the exercise. Many ideas were advanced, some of which showed considerable ingenuity. Thus one student proposed to replace the simple container by a vessel with a thick bottom, the latter having a narrow cavity for the stem of the funnel. This suggestion, however, like several others, had to be rejected because the required apparatus was not available. Finally, a member of the class pointed out that the generators might be used in their original form if some device of acid-resisting material could be inserted which would keep the zinc above the bottom of the stem. This idea appealed to the class, and the requirements were studied which such a support had to meet. Several devices were proposed, one of them, a perforated circular plate, resting upon a cylinder of glass and touching the walls of the generator. But how to insert such a plate? How to pass it through the contracted opening of the bottle? The class pondered this question. It became evident that a flexible material had to be used. "How about rubber," a student asked. The idea was examined from all angles. One by one the advantages which rubber offered became apparent. It could easily be cut to size and provided with a hole for funnel and acid. If the diameter of the plate were made slightly larger than that of the bottle, it could be forced into place and would stay there on account of the friction produced. After all these points had been thoroughly studied, the class proceeded to rebuild the generators once more. The bottles were opened again, cleaned, and dried. Then the plates were prepared and inserted. But now an unexpected difficulty seemed to arise. How could the apparatus be charged with zinc without the latter falling through the hole in the plate? It did not take long until one of the students found a satisfactory solution. While adding the metal, the funnel had to be held in such a position that the hole was just covered by the end of the stem. Now the bottles were closed and fresh acid introduced through the funnels. Again, some hydrogen was collected and then the gas stream shut off by means of the clamps. The generators responded at once. All of the acid was forced away from the zinc and the gas evolution brought to a complete stop.

The problem was solved and the exercise finished. Great was the satisfaction of the students! But now a surprise awaited them. Out of one of the cases the instructor took a big apparatus, the Kipp generator. At first the attention of the class was diverted by the unfamiliar shape, but soon the principle of the apparatus was recognized. Yet there was no disappointment among the students. They understood the purpose of the exercise—and they liked their generator much better than the "big one."

SUMMARY

Since the exercise just described was the first of its kind given to this particular class, its object had been purposely selected so as to present but a moderate degree of difficulty. However, after having once successfully completed such a project, the students will be eager to match their ingenuity against more complicated problems. Therefore, it will be of interest that adequate topics can be found at almost every stage of the general chemistry course.

A REVIEW *of the* INTERPRETATION *of* pH

MEL GORMAN

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In 1909 Sørensen defined pH by the equation $pH = -\log C_{H^+}$ *in which* C_{H^+} *is the concentration of hydrogen ion in mols per liter. He also described a potentiometric method designed to determine pH. Later developments showed that due to liquid junction potentials and the dependence of electromotive force on activity (instead of concentration) there is an inconsistency between pH as defined and pH as determined potentiometrically. W. M. Clark, using Sørensen's work as a basis, later arbitrarily standardized the pH scale as an experimentally determined series of numbers. His suggestions have been universally adopted. Recently, however, new revised pH scales have*

been proposed which are more consistent with thermodynamically measured ionization constants of weak acids than the previous scale.

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IN THE development of the theory of ionization of electrolytes many of the quantitative relations were based on conductance measurements. After the hydrogen electrode came into general use it was quite logical to use conductance data in the standardization of potentiometric measurements. Thus Sørensen,[1] who originated the concept of pH, calculated that the degree of dissociation in a 0.1 *N* solution of hydrochloric acid is 0.917, and therefore the hydrogen-ion concentration, C_{H^+}, is 0.0917 mol per liter. This value corresponds to a pH of 1.04, where pH is defined as

$$\text{pH} = -\log C_{H^+} \qquad (1)$$

In the cell Pt, H_2(1 atm.) HCl (0.1 *N*)|KCl (3.5 *N*)| KCl (0.1 *N*), HgCl, Hg(I) Sørensen used his pH value of 1.04 for the 0.1 *N* hydrochloric acid in the relation

$$\text{pH} = \frac{E_1 - E_0}{2.303RT/F} \qquad (2)$$

in which E_1 is the observed voltage of the cell with the liquid junction potentials "eliminated" by the now seldom used Bjerrum extrapolation, R is the gas constant in joules per degree, T is the absolute temperature, F is the faraday, and E_0 is a quantity calculated from the other terms. E_0 is considered to be the potential of the tenth normal calomel electrode. Sørensen's value of E_1 is 0.3979 volt at 18°, from which E_0 is calculated to be 0.3380 volt at 18°. In the past this E_0 value has been extensively used in the standardization of buffer solutions and is still widely employed for various purposes.

Subsequent theoretical and experimental developments in the study of aqueous solutions of electrolytes eventually made it evident that an inconsistency existed between pH as defined and pH as determined potentiometrically. In the first place it is now meaningless to speak of the degree of dissociation of hydrochloric acid because according to modern theory the acid is completely ionized. If pH is defined by equation (1) the pH of a 0.1 *N* hydrochloric acid solution is 1.00, and not 1.04. Hence it is obvious that pH calculated from equation (2) would not be equal to $-\log C_{H^+}$. Secondly, the Bjerrum extrapolation is now generally regarded to be invalid. Instead of using the Bjerrum extrapolation it is at present almost universal practice to use a solution of saturated potassium chloride as a salt bridge in order to reduce the liquid junction potential to some small value, and to assume that this potential is negligible. However, Sørensen's E_0 value is used. Of course, this procedure in no way assists in the interpretation of pH numbers. Furthermore, even if all liquid junction potentials could be completely eliminated, the electromotive force of cell (I) would not give any direct information about the concentration of hydrogen ion but would be a function of the mean ion activity of the hydrochloric acid.

Because of the above considerations pH must be regarded merely as a series of arbitrary numbers. Thus, in his recommendations for the standardization of the pH scale, Clark[2] says,

"It shall be assumed, arbitrarily, that in the cell Pt, H_2 (1 atm.)|H^+ (activity X)|KCL (sat.)|KCl (0.1 *N*) HgCl (s)|Hg (II) the potential difference at B remains constant as X varies and that the sum of the potential differences at B, C, and D is 0.3380 volt at 18° (0.3376 volt at 25°).

(A B C D)

"The standard experimental meaning of pH shall be the potential of the above cell considered as positive, less the above value for the calomel half-cell, the difference being divided by the numerical quantity $2.303RT/F$."

It is imperative to note that pH thus defined is entirely experimental and that no reference is made either to the hydrogen-ion concentration, or to hydrogen-ion activity, or to the mean ion activity of the acid. It would be impractical to define pH in terms of the individual hydrogen-ion activity, for it will be remembered that single ion activities cannot be determined thermodynamically.

Most workers have adhered to Clark's standardization, but recently there have appeared modifications of his recommendations in the form of revised E_0 values which are consistent with quantities capable of exact thermodynamic determination. Such quantities are the thermodynamic equilibrium constants for the ionization of weak acids.[3] These constants have been utilized by Hitchcock and Taylor[4] and by MacInnes, Belcher, and Shedlovsky[5] in the establishment of new pH scales. In cells of Type II, the first mentioned workers choose 0.3355 volt at 25° for E_0, and the latter choose 0.3358 volt. In Table 1 the pH values of 0.05 *M* potassium acid phthalate at 25° based on the different E_0 values are listed for comparison.

Although these new pH scales are more logical from the standpoint of consistency with thermodynamic data,

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[1] SØRENSEN, "Études Enzymatiques. II. Sur la Mesure et l'Importance de la Concentration des Ions Hydrogène dans les Réactions Enzymatiques," *Compt. rend. trav. lab. Carlsberg*, **8**, 1–168 (1909).

[2] CLARK, "The determination of hydrogen ions," 3rd ed., Williams and Wilkins Co., Baltimore, Md., **1928**, p. 480.

[3] HARNED AND EHLERS, "The dissociation constants of acetic acid from 0 to 35° Centigrade," *J. Am. Chem. Soc.*, **54**, 1350–7 (Apr., 1932); MACINNES AND SHEDLOVSKY, "The determination of the ionization constant of acetic acid, at 25°, from conductance measurements," *ibid.*, **54**, 1429–38 (Apr., 1932).

[4] HITCHCOCK AND TAYLOR, "The standardization of hydrogen-ion determinations. I. Hydrogen electrode measurements with a liquid junction," *ibid.*, **59**, 1812–18 (Oct., 1937).

[5] MACINNES, BELCHER, AND SHEDLOVSKY, "The meaning and standardization of the pH scale," *ibid.*, **60**, 1094–9 (May, 1938).

TABLE 1

pH VALUES OF 0.05 M POTASSIUM ACID PHTHALATE AT 25°

Clark	*MacInnes, Belcher, and Shedlovsky*	*Hitchcock and Taylor*
3.974	4.000 ± .005	4.008

they are not intended to solve the problem of liquid junctions or to measure the individual activity of the hydrogen ion. MacInnes, Belcher, and Shedlovsky point out that their E_0 value gives pH numbers which are not equal to $-\log C_{H^+}f_{\pm}$ but are probably as close as they can be made to conform to such equality using the unmodified equation

$$\text{pH} = \frac{E - E_0}{2.303RT/F} \qquad (3)$$

C_{H^+} is the concentration of the hydrogen ion, $f_{\pm}$ is the mean ion activity coefficient of the acid in the hydrogen half-cell, and E is the observed electromotive force with no correction for liquid junction attempted in a cell of Type II.

The fact that pH is merely an index number which more or less approximates $-\log C_{H^+}f_{\pm}$ must not be construed to mean that the concept of pH is useless or that the vast accumulation of data gathered with the aid of this concept is worthless. The distinct advances which have been made and are being made in biological and chemical research and in industrial progress attest to the useful application of pH measurements.

A GEOMETRIC MEANS OF TEACHING SOLUBILITY PRODUCT

GEORGE W. JOSTEN

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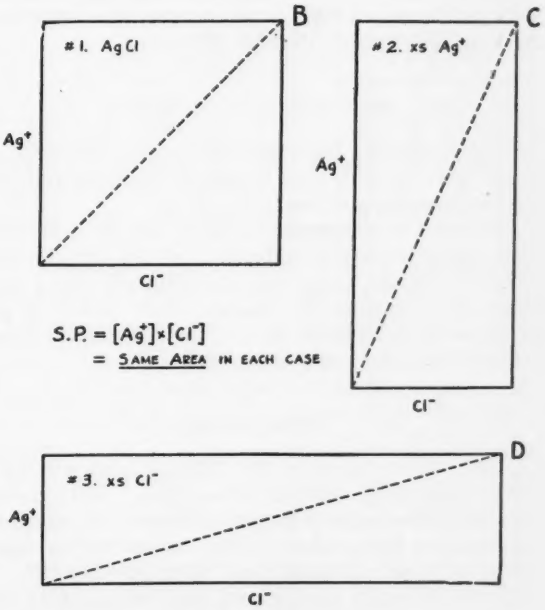
THE college student in chemistry generally meets with the idea of the solubility product of a substance for the first time in his qualitative activities. His activities previous to this time have included the various geometries and mathematical relationships, which he may or may not care to use again. However, it is possible to use them in terms of area or volume to assist in the explanation of solubility product, along with the explanation expressed in the mass law.

If we consider the simple case of solubility product where we have ions of the same charge in a saturated solution, we have, of course, a product of two factors without exponents. A product of two factors can be represented as an area if we have the solubility of each ion in moles per liter laid out on coördinates. In a saturated solution of the pure salt, for example, AgCl, we could have the square representing an area show the product of the ion concentration, and as always, in moles per liter, an amount, and not the ion itself multiplied by another ion.

At the same temperature, and over a wide range of concentration, we assume that the solubility product is maintained even if the concentration of the ions varies. If the numerical value is maintained, the same area for the same salt, AgCl, is also maintained. But if one of the ion concentrations has decreased, the other has increased, if the solution is to maintain the condition of saturation. This condition can be represented in the vertical rectangle. If the other ion is, however, in greater concentration in moles per liter, we could have the horizontal rectangle which may also have a different shape, but the same area. If there is any advantage in seeing the character of the rectangle better, diagonals can be drawn as shown.

For salts like calcium fluoride, CaF_2, we could have an area, $(F^-) \times (F^-)$, which would be the base of a tetragonal prism of height (Ca^{++}). Magnesium ammonium phosphate could be represented in the ortho-



SOLUBILITY PRODUCT

Applies also in cases like $MgCO_3$ and $AlPO_4$

rhombic system. Other structures will come to mind if the substance in question can be kept in three dimensions.

HIGH-SCHOOL NOTES

ELBERT C. WEAVER

Bulkeley High School, Hartford, Connecticut

CURRICULUM COMMITTEE MEETS

SIX members of the Curriculum Committee of the American Chemical Society, including Chairman Martin V. McGill, met in Cincinnati on April 7–10, 1940. Deliberations of the Committee included (1) ways of increasing membership in the American Chemical Society among high-school teachers; (2) discussion of the effect of decreased enrolment in definite science courses in secondary schools and the growth of generalized science courses; (3) maturing of plans for the summer courses sponsored by the Division of Chemical Education to be given at Western Reserve University, June 17–July 26, 1940: (*a*) Workshop in Chemistry (a list of minimum essentials was presented for discussion by Dr. N. D. Cheronis, a member of the Committee, and general plans were drawn by Dr. R. D. Reed, who will teach at Western Reserve University this summer); (*b*) Demonstrations and Projects of High-school Chemistry (a list of topics to be covered was presented by Dr. Reed).

Recent additions to the membership of the committee include Dr. R. D. Reed, New Jersey State Teachers College, Montclair, New Jersey, and Mr. T. A. Nelson, Decatur High School, Decatur, Illinois.

HEAT TREATMENT EFFECTS

"Bobby pins" or hair clips which can usually be garnered from the girls in a chemistry class are suitable steel for showing heat treatment effects.

The wire is straightened and heated in a Bunsen flame until the color is uniform. Sudden quenching in a beaker of water makes hard steel so brittle that a very short piece snaps in the fingers. Slow cooling in air produces a soft pliable wire. Restoring the original temper is an interesting test of skill.

SUGGESTIONS

Move the electrodes in the ordinary open wire-light bulb conductivity tester closer together. Hold in contact with them a piece of glass tubing which has been softened in a Bunsen flame. The conductivity of fused salts is thus demonstrated quickly.—ELBERT C. WEAVER, Bulkeley High School, Hartford, Connecticut.

A fluorescent screen can be made cheaply by coating a piece of white paper with boot grease (which may be purchased from Sears, Roebuck and Company). When illuminated by light from a mercury-vapor lamp, the vapors of mercury show against this screen as a shadow, a sensitive test. Cinnabar ore heated in a Bunsen flame produces a definite shadow, as does warm air blown over an open dish of elementary mercury.—ERNEST A. JUST, Polytechnic High School, Long Beach, California.

INQUIRY

Who has a simple lecture demonstration to show valence? Law of combining gas volumes? An equilibrium?

RESPONSE TO INQUIRY[1]

I am of the opinion that the mechanical energy put into the spring goes off as excess thermal energy when the wound spring is dissolved. This excess thermal energy may be due to increased inter- or intra-molecular activity. Furthermore, I do not believe that we could measure this energy, because the excess amount of heat given off is so very small. As an illustration of this point: if we do 100 ergs of work on the spring in winding it, in order to get the heat which this spring can produce we must divide 100 by the mechanical equivalent of heat, 4.18×10^7. The quotient, expressed in calories, is a minute immeasurable quantity. Therefore, the spring gives up its potential mechanical energy in a minute amount of thermal energy.—JACK ALESHNICK, 755 South Twelfth Street, Newark, New Jersey.

A BIOGRAPHY OF LOMONOSOV

GLENOLA BEHLING ROSE

Penns Grove, New Jersey

Under the title "Life of Lomonossove, the Celebrated Poet of Russia," there is a short biography in *Panorama*, 149–56 (London, 1807), written in English by Alexei Evstafiev. It does not agree in all biographical statements with Smith or Menshutkin, but it adds nothing of importance for the chemist. It gives no details concerning Lomonosov's scientific work, merely mentioning that his scientific achievements especially in mineralogy and chemistry were so great that his "country will forever be indebted to him for the progress of science."

[1] J. CHEM. EDUC., 17, 96 (Feb., 1940).

RECENT BOOKS

SEMIMICRO QUALITATIVE ANALYSIS OF INORGANIC MATERIALS. *W. B. Meldrum*, Professor of Chemistry, Haverford College; *E. W. Flosdorf*, Assistant Professor of Bacteriology, University of Pennsylvania; and *A. F. Daggett*, Assistant Professor of Chemistry, University of New Hampshire. American Book Company, New York City, 1939. xiv + 354 pp. 22 figs. 14 × 22 cm. $2.75.

Texts of qualitative analysis have been appearing in such quick succession that the interest of chemistry teachers and of chemists in general can be aroused only when some definitely new features, methods or points of view are presented. This was certainly the case with the QUALITATIVE ANALYSIS OF INORGANIC MATERIALS by the first two of the present three authors, a book which has been reported on by another reviewer in the December, 1938, issue of THIS JOURNAL and the main feature of which was a new systematic analysis of the anions. The *macro* methods expounded in the previous book are now transformed into *semimicro* methods without any change in their chemistry. Quantities of materials are usually one-tenth or less of their values in the *macro* methods. Precipitations are carried out in 3-ml. conical centrifuge tubes. Separations are accomplished in a centrifuge of 1500 R.P.M., the supernatant liquid being removed by means of a dropper pipet. The whole technic of semimicro manipulations is presented in four pages (pages 170–3).

Large portions of the two books are identical word for word. Part I, devoted to Fundamental Principles, now occupies one hundred fifty-seven pages instead of eighty-six and can be regarded as a sound and satisfactory account of the elements of the physical chemistry of solutions. Several additions to the previous text are welcome, for instance the paragraph on hydroxide complex ions (pages 132–4). We would have liked to see the authors use the evidence in favor of these ions ($Zn(OH)_4^=$ for $HZnO_2^-$, and so forth) instead of leaving the matter undecided. We fail, moreover, to see why only the formulas of the $HZnO_2^-$ type correspond to the amphoteric behavior of $Zn(OH)_2$, since the two equilibria

$$Zn^{++} + 2OH^- \rightleftharpoons Zn(OH)_2 \rightleftharpoons H^+ + HZnO_2^-$$

can, in the new interpretation, be written as

$$Zn(H_2O)_4^{++} + 2OH^- \rightleftharpoons Zn(OH)_2 + 4H_2O \rightleftharpoons 2OH_3^+ + Zn(OH)_4^=$$

Part II, devoted to Laboratory Work, occupies one hundred seventeen pages instead of one hundred fourteen, but the Reactions of the Ions, previously included in this section, are now more clearly presented in a separate section of forty-three pages. The Appendix is largely similar to that of the previous book. A useful addition is a list of references for special reagents (pages 342–4).

It is interesting to note that all the methods and particularly the new analysis of the anions have been thoroughly and satisfactorily tested in their semimicro form in the classes of one of the authors. Repeated testing of this type is highly desirable in order to regulate and guide the trend toward the general use of semimicro methods in elementary college courses.

PIERRE VAN RYSSELBERGHE

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DAS CHEMISCHE FEUERLÖSCHWESEN. *Dr. Oskar Kausch.* Volume 21 of the Series CHEMIE UND TECHNIK DER GEGENWART edited by *Dr. H. Carlsohn*, Professor at the University of Leipzig. S. Hirzel, Leipzig, 1939. xi + 283 pp. 89 figs. 15 × 25 cm. Paper cover, R.M. 17; cloth bound R.M. 18.50 ($5.35, plus postage, New York City).

The manufacture, storage, and industrial, as well as domestic applications of the large variety of inflammable solids, liquids, and gases used today has increased greatly the fire hazard in homes and industry and has made it necessary to devise constantly new and more efficient means of fighting fires from these new as well as old hazards. Although water is still employed today, the use of chemicals of various types has been of great aid to the modern fire fighter in his never-ending struggle against this destructive force. It has been the object of this book to describe all these methods in which chemical compounds or elements are used, either directly or indirectly after chemical transformation, to combat fires. In this attempt the author has been remarkably successful. The parts played by solids, liquids, gases, vapors, and chemical foam as well as the more recent development known as air foam (sometimes called mechanical foam) in our modern methods of fire extinguishment, are discussed fully in different chapters from the beginning of their use up to the present time. The German and foreign scientific and patent literature is considered in detail, and modern commercial fire extinguishers and fire fighting installations marketed in Germany are shown in many illustrations. Various types of fire extinguishers approved for use in Germany by the "Feuerwehrbeirat" are listed in tables. Following the descriptive section of the book there is given a patent index, a list of patentees, literature references, a list of important fire hazards, and a subject index.

Although this book was evidently written principally for use in Germany, the American reader will obtain from it an excellent description of the use of chemicals in our current fire-fighting operations. However, he will look in vain for information concerning American methods and American applications of the chemical facts discussed. American extinguishers and fire-fighting installations are neither described nor shown, in spite of the fact that research laboratories of various American manufacturers are constantly making contributions to the science of fire fighting. Likewise the part played by such organizations as the Underwriters' Laboratories, Inc., the Inspection Department of the Associated Factory Mutual Fire Insurance Companies, The National Bureau of Standards in Washington, D. C., and others in the establishment of minimum standards for modern fire protection is not described.

The format of the book has been well chosen. The printing is good and the clear, distinctive illustrations are quite satisfactory. The reviewer found only a very few typographical errors of minor significance. It would be helpful if in subsequent editions the year of issue be given for each patent cited.

LEOPOLD SCHEFLAN

PYRENE MANUFACTURING COMPANY
NEWARK, NEW JERSEY

THERMODYNAMICS AND CHEMISTRY. *F. H. MacDougall*, M.A. Ph.D., Professor of Physical Chemistry, University of Minnesota. Third Edition. John Wiley & Sons, Inc., New York City, 1939, ix + 491 pp. 53 figs. 15 × 23 cm. $5.00.

Those who are familiar with earlier editions of this book will find the third edition practically an independent work. It has been almost entirely rewritten and enlarged about twenty-five per cent., yet the excellence of style, order, and so forth, has been retained. Professor MacDougall has succeeded in giving life and warmth to the ordinarily cold abstractions of thermodynamics. The purist will be disturbed by the inclusion of such extra-thermodynamic subjects as Debye-Hückel theory and quantum and statistical mechanics, but the value and interest of the book is undoubtedly enhanced thereby. These subjects, as well as heat, fugacity, activity and activity coefficients, electromotive force and electrical potential, have been discussed very much more extensively. Entirely new are chapters on mathematical procedures and the thermodynamics of gravitational, centrifugal, and electrical fields and surface tension. New also is the statistical interpretation of entropy. Unusual

in a text on thermodynamics is the extensive discussion of phase rule applications.

All the topics considered in the better works on the subject are taken up, usually in considerable detail. Especially commendable is the treatment of deductions from the first and second laws, thermodynamic functions and equilibrium, chemical potentials, electromotive force and the free energy of cell reactions, and so forth. Not usually found in other comparable texts is a chapter on special cases of ionic equilibria. Unusual attention is paid to critical phenomena. In 1920 the author stated, "It has been my endeavor to write a book which, in addition to being accurate, logical, and sufficiently rigorous, will furnish the student with numerous examples of the application of the principles of the science." The latest edition certainly realizes that aim. Quite obvious to any reader is the meticulous care with which the author defines his terms, *e. g.*, in his distinction between the various activity coefficients, between electrical potential and electromotive force, and so forth. His derivations are quite detailed, seldom requiring the user to fill in huge gaps.

The symbols used are those common to American conventions. Chemical potential is preferred generally in lieu of partial molal free energy. A compact tabulation of all symbols should, however, have been included. Extensive sets of problems, without answers, are found at the end of each chapter. Literature references are not very numerous but are adequate. There are fifty-three tables of useful data. Reference is made to heat capacity equations for gases, but these are not given. Their inclusion, together with an illustration of their application in computing heats of reaction at various temperatures, would seem desirable. Graphic integration could be used more extensively than is the case and $\log_e$ could be replaced profitably by ln. Format and type are very good.

In conclusion, one may say this is an excellent piece of work for which the author is to be congratulated. It can be heartily recommended as a text in thermodynamics or as a reference book in related subjects.

MALCOLM M. HARING

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PHYSIK FÜR STUDIERENDE AN TECHNISCHEN HOCHSCHULEN UND UNIVERSITÄTEN. *Ingenieur Dr. Paul Wessel*, Lecturer, Wigan and District Mining and Technical College, Wigan. Edited by *Dr. V. Riederer von Paar*. Ernest Reinhardt in München, 1938. xii + 550 pp. 277 figs. 12 × 20 cm. RM. 4.90.

This textbook "is intended to provide a clear understanding of physical phenomena with the simplest possible statements." It is to serve as an outline of introductory collegiate physics for students, especially in the technical and applied fields, who would be spared a vast taking of notes in lectures and so be enabled to direct attention more fully to the lecture itself and to the illustrative experiments. A summary is offered to the reader as a general comprehensive survey, in abbreviated form, of the essential facts of physics, including much of "modern physics." The author, from his engineering viewpoint, aims to interest technically minded readers by emphasis of the relation of the basic fundamentals of physics to technics and by illustrations of their application.

The book is divided into three main parts. I. "Outline of Physics, First Half" (one hundred fifty-eight pages), subdivided into Mechanics (1) of Solid Bodies (thirty-nine pages), (2) of Liquid Bodies (nine pages), (3) of Gaseous Bodies (eight pages); Wave Theory (seven pages) and Acoustics (six pages); Calorics (twenty-five pages); and Optics (sixty-four pages).

II. "Outline of Physics, Second Half" (one hundred ninety-six pages), consisting of Magnetics (twelve pages); Electrics, discussed under Electrostatics (seventeen pages), Electrodynamics (seventy-seven pages), Electromagnetic Waves and Corpuscular Radiations (forty-eight pages); and Electronics and Atomistics (forty-two pages).

III. "Short Review and Collection of Formulae" (fifty-nine pages); Test Questions and Answers (sixty-three pages); Tables and Constants (thirty-eight pages); and a very comprehensive Index (thirty-six pages).

Parts I and II are somewhat similar in idea and content to the outlines of physics published in this country. In this text, however, more than in others of the same nature, such topics are stressed as optical effects of magnetic fields, electromagnetic waves, photoelectricity, X-rays, atomic structure, the photon, natural and artificial disintegrations, relatively, quantum theory, De Broglie waves, the uncertainty principles.

A novel feature is the "Short Review and Collection of Formulae," which summarizes the three hundred fifty-four pages of the outline concisely into fifty-nine pages. In addition there are 1447 "Test Questions and Answers," the answers consisting of page references to Parts I and II. None of the questions requires numerical solutions. Besides the usual tables among the twenty-nine given is that of "Mass-einheiten" in which are tabulated for the various fundamental terms of physics the length-mass-time dimensions, the absolute units, the practical physical units, the technical units, the legal international units and the associated equations.

The author presents in clear and precise statements the whole field of physics in systematic order, easily understandable, making no use of mathematics beyond basic trigonometry. The numerous illustrations (two hundred seventy-seven in number) amply and fully serve their purpose. Equations are not derived, although the meaning of each letter is carefully denoted. Further explanations are given by illustrative numerical problems (one hundred six throughout the book), solved carefully in detail, with especial regard to dimensional units.

This text should be of interest to all teachers of physics for comparison of content in an introductory course in physics, especially as regards the field of "modern physics." Its concise, systematic collection of physics principles should be useful to all students of physics in both the theoretical and applied fields. For those interested in such fields as technics, chemistry, medicine, and so forth, it should serve as an admirable introduction to the application of physics principles to those fields, especially in regard to the latest phases of physical investigation.

CHARLES G. EICHLIN

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LABORATORY MANUAL TO ACCOMPANY INTRODUCTORY GENERAL CHEMISTRY. *Harold G. Dietrich* and *Erwin B. Kelsey*, Assistant Professors in Chemistry, Yale University. Revised Edition. The Macmillan Co., New York City, 1938. ix + 118 pp. 19 × 25 cm.

This revised second edition of Dietrich and Kelsey is designed to accompany Brinkley's INTRODUCTORY GENERAL CHEMISTRY. The first and larger section of the manual is entitled "Inorganic Chemistry." Section II is devoted to Qualitative Analysis.

The exercises in Inorganic Chemistry are written "primarily for the student who has had no previous chemical education," but a great number of them are admirably suited to "the individual who has had an exposure to the subject." To challenge students of the second group there are excellent experiments of a semi-quantitative nature in eleven of the thirty-seven exercises. The exercises frequently contain more experiments than could normally be covered in a single period. This allows for selection by the instructor.

There are numerous questions throughout the text, with additional numbered questions at the end of each exercise. Alternate blank pages on the right of each page of description are allowed for answers. Summarized data sheets are provided for the quantitative experiments and for several of the review questions. The arrangement of the book with spiral wire binding does not permit of removal of these sheets without mutilating them.

The content of the first section includes twelve of the usual exercises on non-metals and their compounds, seven exercises devoted to metals and brief methods of separation. Interspersed with the foregoing are the well-written exercises pertaining to

principles, laws, quantitative relations, and so forth. There are two exercises on ionization and electrolysis and an advanced one covering electrical energy from chemical changes. The section concludes with two exercises treating fuels and hydrocarbons. More illustrations and figures might be employed in the Inorganic Section.

The authors require frequent consultations between student and instructor by allowing for student development of certain experiments. This plan is good, where strict supervision is maintained.

Section II is the latter third of the manual devoted to Elementary Qualitative Analysis. Its analytical details are well worked out as would be expected from followers of Gooch and Browning. There is little fluff and theory, but a sufficient number of pregnant questions to accompany a good class text. Outlines of analysis are shown by large flow sheets. Strengths of solutions are not always specified, but lists of reagents and their concentrations are given in the appendix.

The manual is well written, well edited, and poorly bound. So fine a group of experiments merits a better housing.

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INTRODUCTION TO ORGANIC CHEMISTRY. *Hippolyte Gruener* and *Herman P. Lankelma*, Western Reserve University. American Book Company, New York City, 1939. viii + 533 pp. 13.5 × 22 cm. $3.00.

This text is written primarily for the liberal arts student who desires to include organic chemistry for its cultural value in his background of a general education. In order to present the logical development of the science as the chemistry of the hydrocarbons and their derivatives, the forty-eight chapters are grouped under five parts: Part I: Open-Chain Hydrocarbons and Their Derivatives; Part II: The Benzene Hydrocarbons and Their Derivatives; Part III: Completion of the Hydrocarbon Series; Part IV: Heterocyclic Compounds; and Part V: Special Topics.

Only a few of the more important methods of preparation and properties of the many classes of compounds are given. There is little discussion of the type of argument used to determine the structure of individual compounds, and practically no presentation of modern ideas of valence and atomic structure as applied to organic problems. Rather, emphasis is placed upon such topics of general human interest as industrial applications, and discoveries of medical and biochemical significance. There is little material of a historical nature in the text.

It should prove an interesting experiment in chemical education to follow the reception of a book which makes such a radical break from the rigorous treatment of the science as found in the widely used texts of Lucas and Conant.

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KURZES LEHRBUCH DER PHYSIKALISCHEN CHEMIE, Hefte I Grundprinzipien der Physikalischen Chemie. Lehre von den reinen Stoffen und Mischungen von Nichtelektrolyten (Physikalisch-Chemische Thermodynamik). *Dr. Karl Jellinek*, Em. Professor an der Technischen Hochschule Danzig. N. V. Uitgevers-Maatschappij AE. E. Kluwer, Deventer (Niederlande), 1938. xii + 314 pp. 163 figs. 37 tables. 16 × 25 cm. 8.50 hfl.

The KURZES LEHRBUCH DER PHYSIKALISCHEN CHEMIE represents the author's attempt to compact his very comprehensive five-volume text, together with his many years of experience in teaching the subject, into a usable short textbook. The complete work, of which the present volume constitutes Part I, Physical-Chemical Thermodynamics, will appear in four parts, with a treatment of Electrochemistry, Phase Rule and Colloids in Part II, Structure of Matter in Part III, and Photochemistry and Wave Mechanics, Part IV.

The Thermodynamics part includes sections on Basic Principles (*e. g.*, first and second laws, perfect gas law, Maxwell distribution law); Pure Substances (gases, liquids, solids, interphase equilibria); Dilute Gaseous Mixtures (gaseous equilibria); Dilute Liquid Mixtures of Non-Electrolytes (theories of solution); Concentrated Mixtures of Non-Electrolytes in Various States of Aggregation (activities, deviations from ideal solution, solid solution, and so forth).

In treating detailed topics, the empirical facts, accompanied by an excellent, though brief, description of experimental methods are first presented. A derivation of the thermodynamical equations used to account for the experimental findings is then given. Wherever possible, the kinetic or statistical approach to the same problem is indicated. Due to the physical proximity of experiment and theory, such a development serves, in a very limited fashion, to correlate the two. It falls far short, however, of the logical culmination of such an approach—to show how the experimental facts led to the particular interpretation and how, in turn, the theory suggested new experiments. Too many of our "modern" texts fail completely to demonstrate the scientific method as it was actually (historically) applied and thus leave the student with a sense of the "unreality" of the equations he is required to use.

Especially to be commended is the large number of illustrative problems which have been worked out in detail. The derivations of equations are very complete and, in fact, often overstep in the direction of too much detail (*e. g.*, page 309; problems, pages 152–60). An excellent, up-to-date bibliography appears in the form of footnotes.

The inclusion of both the "cycle" and "free energy" treatment of the various subjects (*e. g.*, Clausius-Clapeyron equation, pages 110–11; equilibrium constants, pages 180–90) is of very questionable value, particularly since it leads to a large expansion of the text without compensating advantages. The Lewis and Randall terminology is adopted, and it would thus seem that the free energy treatment should suffice.

The attempt to cram as much material as possible on a page has resulted in a very confusing arrangement. The various sections of a page are often inadequately separated (text and footnote, same type, separated by small marker, pages 56, 130, 254; Figure 99 so reduced that legends are difficult to read). It is unfortunate that poor spacing and a very limited selection of type should mar an otherwise excellent printing job.

This short textbook is to be recommended as a fairly complete and useful reference for those who do not possess the author's larger work. Its appearance in a foreign language will, of course, restrict its use to secondary reference purposes in elementary physical chemistry courses.

JOSEPH GREENSPAN

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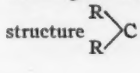
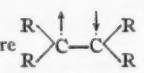
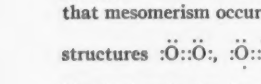
TAUTOMERIE UND MESOMERIE. *Dr. Phil. Bernd Eistert.* Verlag von Ferdinand Enke in Stuttgart, Stuttgart-W, Germany, 1938. 1 + 204 pp. 16 × 24.5 cm. RM. 15.80.

In spite of its title, this book has comparatively little to say about tautomerism but is almost entirely devoted to a discussion of mesomerism (resonance). The point of view throughout is that of an organic chemist, and the quantum mechanical basis of the theory is hardly touched upon. Although this is doubtless an advantage for those readers who do not have the requisite mathematical and physical background, it also introduces certain weaknesses. For example, the theory of mesomerism is made to appear in the light of an *ad hoc* hypothesis to an unnecessary extent. More serious is the fact that a number of rather fundamental errors are to be found. These include, among others, the meaningless distinction drawn on page 75 between the normal structure  of a symmetrical ethylene, in which all

electrons are paired and the "loosened" structure  in which two of the electrons are supposed to be unpaired but to have opposed spins. Since two electrons with opposed spins are, by definition, paired, these structures are not mesomeric but identical. A similar error is found on page 151, where it is stated that mesomerism occurs in the oxygen molecule among the three structures  . Of these, the second is identical with the first if the two electrons shown isolated are supposed to have opposed spins, while, on the other hand, it cannot resonate with the others if those two electrons are supposed to have parallel spin; in neither case can the first and third structures be reconciled with the paramagenetism of the molecule. On the other hand, the reviewer is glad to note that the difficult distinction between tautomerism and mesomerism is drawn both clearly and correctly.

Although there are brief chapters on applications of the theory of mesomerism to the question of intermolecular forces and to the relationship between constitution and color, the major portion of the book is concerned with applications to the reactions of organic molecules. It is inevitable that in such a new and rapidly changing field there should be differences of opinion on a number of points. The reviewer, for example, is unable to agree that the author's alternating inductive effect (A-Effekt) in saturated chains is either theoretically sound or consistent with the weight of experimental evidence. He is also unable to agree that the picture of orientation of substituents in aromatic rings presented by the author is as generally satisfactory as that due to Robinson and to Ingold. It would be a mistake, however, to dwell at too great length on such points as these, which are perhaps not yet out of the controversial stage. In any case, it cannot be denied that the book makes interesting and thought-provoking reading for anyone who would like to know something about the "why" as well as the "what" of organic chemistry.

G. W. WHELAND

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ANNUAL REVIEW OF BIOCHEMISTRY, Volume VIII. *James Murray Luck*, Editor, and *James H. C. Smith*, Associate Editor. Annual Reviews, Inc., Stanford University Post Office, California, 1939. ix + 676 pp. 15 × 22.5 cm. $5.00.

Volume VIII of the Annual Review of Biochemistry contains the following chapters: "Biological Oxidations and Reductions," M. Dixon (pp. 1–36); "Proteolytic Enzymes," K. Linderstrøm-Lang (pp. 37–58); "Nonproteolytic Enzymes," K. Myrbäck (pp. 59–80); "Polysaccharides and Lignin," K. Freudenberg (pp. 81–112); "X-Ray Studies of the Structure of Compounds of Biological Interest," W. T. Astbury (pp. 113–32); "The Chemistry of the Acyclic Constituents of Natural Fats and Oils," R. J. Anderson and L. F. Salisbury (pp. 133–54); "The Chemistry of Proteins and Amino Acids," A. Tiselius (pp. 155–84); "The Chemistry and Metabolism of the Compounds of Sulfur," G. Medes (pp. 185–210); "Carbohydrate Metabolism," I. L. Chaikoff and A. Kaplan (pp. 211–30); "Lipid Metabolism," W. M. Sperry (pp. 231–48); "Metabolism of Proteins and Amino Acids," R. W. Jackson and J. P. Chandler (pp. 249–68); "Mineral Metabolism: Calcium, Magnesium, and Phosphorus," D. M. Greenberg (pp. 269–300); "Hormones," J. Freud, E. Laqueur, and O. Mühlbock (pp. 301–48); "Choline as a Dietary Factor," C. H. Best and J. H. Ridout (pp. 349–70); "The Water-Soluble Vitamins," C. G. King (pp. 371–414); "Fat-Soluble Vitamins," E. M. Nelson and C. D. Tolle (pp. 415–34); "Metabolism of Brain and Nerve," J. H. Quastel (pp. 435–62); "The Alkaloids," L. Small (pp. 463–82); "Chemical Aspects of Photosynthesis," H. Gaffron (483–502); "Mineral Nutrition of Plants," J. W. Shive and W. R. Robins (pp. 503–20); "Growth Hormones in the Higher Plants," F. W. Went (pp. 521–40); "Animal Poisons," C. H. Kellaway (pp. 541–56); "Ruminant Nutrition," H. R. Marston (pp. 557–78); "Immunochemistry," M. W. Chase and K. Landsteiner (pp. 579–610); "The Biochemistry of Yeast," E. I. Fulmer (pp. 611–26).

The volume also contains author and subject indices.

OTTO REINMUTH

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KURZES LEHRBUCH DER PHYSIKALISCHEN CHEMIE. *Dr. Hermann Ulich*, Professor für physikalische Chemie der Technischen Hochschule Aachen. Theodor Steinkopff, Dresden and Leipsig, 1938. xvi + 315 pp. 15 × 24 cm. 12 RM.

The book is designed to give the student of chemistry, physics, metallography, engineering, and biology an adequate view of physical chemistry in a single volume. The first chapter deals in adequate fashion with the gaseous, liquid, and solid states and introduces solutions. After this the use of thermodynamics is emphasized in dealing with homogeneous and heterogeneous chemical equilibria, including a brief treatment of electrochemistry. Chapter III includes a treatment of kinetics in homogeneous and heterogeneous systems with examples of acid-base catalyzed reactions, contact catalysis, and diffusion processes. The fourth section gives an excellent picture of the forces between atoms and molecules.

The author, by a wise choice of material, has succeeded in his purpose. The book is recommended to teachers and students of physical chemistry.

MARTIN KILPATRICK

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THE OXIDATION STATES OF THE ELEMENTS AND THEIR POTENTIALS IN AQUEOUS SOLUTIONS. *Wendell M. Latimer*, Ph.D., Professor of Chemistry, University of California. Prentice Hall, Inc., New York City, 1938. xiv + 352 pp. 2 figs. 15 × 21 cm. $3.00.

To the average chemist the most valuable part of this book will probably be the appendix, particularly the table of free energies. This table contains over five hundred critically evaluated standard free energies of formation. The appendix also includes summaries of Oxidation-Reduction Potentials, Equilibrium Constants, the Activity of Strong Electrolytes, and Entropy Values.

The first chapter consists of a brief account of the general methods of determining half cell potentials from E.M.F. measurements, equilibrium studies, and thermal data. In the second chapter the indirect methods of obtaining half cell potentials from such quantities as ionization potentials, electron affinities, energies of hydration, and lattice energies are discussed. The other nineteen chapters are devoted to a critical discussion of the original experiments and computing methods upon which the data given in the appendix are based. In general, the terminology and conventions used are those of Lewis and Randall.

While this volume is in no sense a textbook, it is difficult to imagine a monograph on a chemical subject of wider appeal or of more general utility. A critical summary such as this book has long been needed; it will certainly facilitate the work of many chemists.

ROBERT LIVINGSTON

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GROWING PLANTS WITHOUT SOIL. *D. R. Matlin.* Chemical Publishing Co., Inc., New York City, 1939. 14 × 21.5 cm. 137 pp. $2.00.

VOCATIONAL EDUCATION. *J. D. Russell.* U. S. Government Printing Office, Washington, D. C., 1938. x + 325 pp. 14.5 × 23.5 cm. $.40.

NORRIS WATSON RAKESTRAW

EDITOR'S OUTLOOK

VALEDICTORY. The writer begins for the last time the variegation of the fair surface of a virgin editorial page in a mood of deep humility. It would seem that some fifteen years of close and interested observation of the educational scene, of digestion of the best ideas of the more progressive and articulate workers in the field, and of independent prayerful meditation, should constitute the basis for a few illuminating and inspiring "last words." Yet the printer's deadline overtakes us, as usual, in an anxious consciousness of woeful inadequacy to the occasion.

Surveying in retrospect this period of our own education, we find that we know for certain considerably less than we did fifteen years ago. Although we are still obstinate and opinionated enough at times, we find less use than formerly for full, round, resonant obviouslys and indubitablys. The hesitant howevers, nevertheless, and on-the-other-hands develop an increasing tendency to crowd them into the background of our vocabulary. You can scarcely pin us down to an unequivocal yes or no on any reasonable educational question. These could be the symptoms of premature nervous and intellectual senility; we hope they are evidences that we know somewhat less that isn't altogether so.

We have already privately transmitted to our competent and energetic successor, Dr. Rakestraw, the few scraps of information and counsel we thought it not too presumptuous to offer, and stand ready to supplement them, in so far as we are able, upon request. Therefore, in leavetaking we content ourselves in once more acclaiming publicly and thanking personally the splendid group of professional altruists who, despite the retiring editor's sins of commission and omission, have succeeded in preserving and strengthening an invaluable educational institution in troublous times, and who will continue to coöperate in raising it to new levels of excellence.

MEN *and* MACHINES *in* EARLY HARVARD SCIENCE[1]

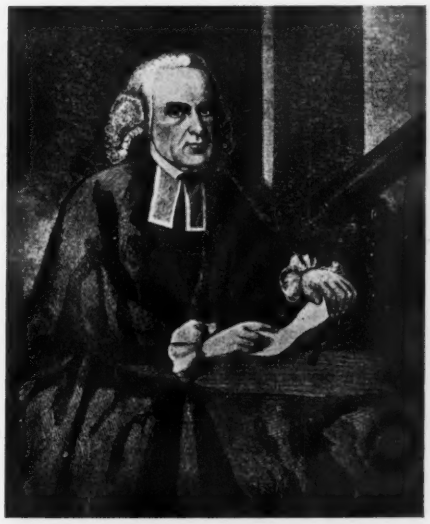
ALLEN D. BLISS[2]

Harvard University, Cambridge, Massachusetts

HARVARD COLLEGE had its origin in an act of the General Court (Legislature) of the Massachusetts Bay Colony, which on September 8, 1636, voted to charter a college and made an appropriation of four hundred pounds for the purpose. Like much modern legislation, this act in itself could not produce a college, and on November 15, 1637, it was voted to locate the new college in Newtown rather than Salem, and a Committee of Twelve was appointed to carry out the act. The Committee chose Nathaniel Eaton and placed him in complete charge of the project: providing staff and buildings, collecting and handling the funds, finding, instructing, feeding, housing and supervising the students. All this progressed slowly, during which time the General Court changed Newtown to Cambridge (May 2, 1638), and soon thereafter the new college received its name. John Harvard was educated in England, came to America in the summer of 1637, lived and preached in Charlestown for several months, and died there of tuberculosis on September 14, 1638. Harvard had been a friend of Nathaniel Eaton and left his library of some four hundred books as well as one-half of his estate (amounting to several hundred pounds) to the Colony for the establishment of a college. This bequest was allotted to the newly formed institution, and it was given the name of its benefactor (by vote of March 13, 1639). There is a popular misconception (of very early origin) that John Harvard founded the college; actually it already was in existence, the Harvard bequest doing much to help it to its feet.

Actual records are lacking, but it seems very likely that Master Eaton "started school" before September 7, 1638 (while John Harvard was on his death-bed), with perhaps a dozen-odd students, a faculty of himself, and Mrs. Eaton in charge of student bed and board. Disciplinary and dietary troubles marred this first year of educational work, and in the summer of 1639 Eaton was in court for beating his newly hired collaborator, "Usher" Briscoe, misuse of college funds, and allowing Mrs. Eaton to serve the students with bad food, or, at times, none at all. Eaton escaped from town without paying his fine, and school closed.

In August of 1640 the Reverend Henry Dunster, newly arrived from England, was appointed President of Harvard College, reorganized the school, and resumed educational work with such good results that the first Commencement was held in 1642. As a report of his work and for publicity, President Dunster issued in 1642 a pamphlet entitled "New England's First Fruits." A study of this report shows that in 1642 the college course required three years, each school year being divided into four quarters, with no vacations. The A.M. degree was given at the end of three more years with evidence of work and proficiency.



JOHN WINTHROP

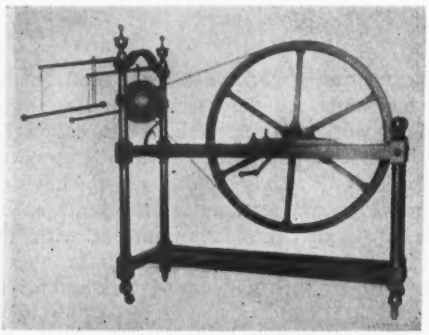
The President did practically all of the actual teaching, with some tutorial assistance, the curriculum consisting mainly of Greek, Latin, logic, and theology. The science instruction comprised a quarter each of physics and botany for first-year men, and arithmetic, geometry, and astronomy for the seniors. This schedule was maintained with occasional difference of content and emphasis (resulting from personnel changes) for many years. About 1653 President Dunster lengthened the course to four years, to equal the requirement in English universities, but did not change the three years for the A.M.

College catalogs being a creation of the last century, and records containing little other than official and financial matter, it is somewhat hard to ascertain the

[1] Presented before the Division of the History of Chemistry at the ninety-eighth meeting of the A. C. S., Boston, Mass., September 12, 1939.

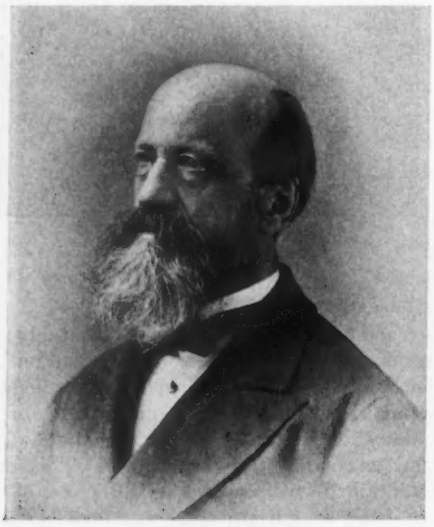
[2] Present address: Yale University, New Haven, Connecticut.

effects of time on Harvard course offerings of this period. A report by the president about 1694 and a listing in 1726 show officially about the same curriculum as in 1642, but other evidence indicates progress and expansion. Geography appeared in the list,



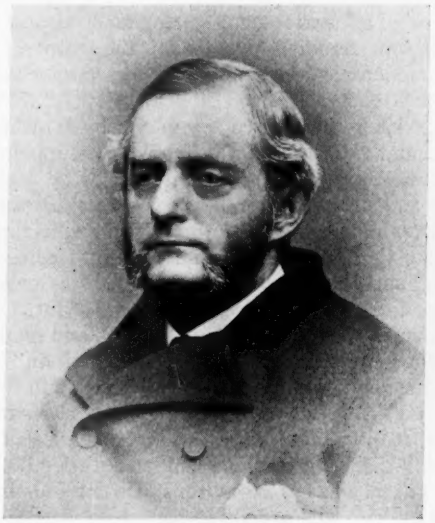
STATIC MACHINE, PROBABLY GIVEN TO HARVARD COLLEGE IN 1764–1766 BY BENJAMIN FRANKLIN

instruction was given in trigonometry, surveying, and navigation, and a telescope was acquired and used diligently after 1672. By 1723 physics, which contained, of course, all that was known of chemistry, was given to each of the three upper classes. The teaching method at that time in nearly all subjects



JOSEPH LOVERING

was to provide a synopsis or course outline, and then fill this in by lectures and required reading. In the early decades the physics outline was based on the old Peripatetic philosophy, but a change was made soon after 1686, with the "adoption" of Charles Morton's "Compendium Physicae" as a text. Morton was a well-educated and experienced English scholar who came to the Colony in 1686 with the hope of succeeding to the Presidency of Harvard. In this he was disappointed, but he was chosen to the Harvard Corporation in 1692, his scholarly and modern book was much used by the students (with a considerable increase in physics "Majors"), and his scientific influence was very wide. Medical instruction was not given systematically as



JOSIAH PARSONS COOKE

such at Harvard prior to the Revolution; many graduates, however, studied with practicing physicians and joined the profession in that way.

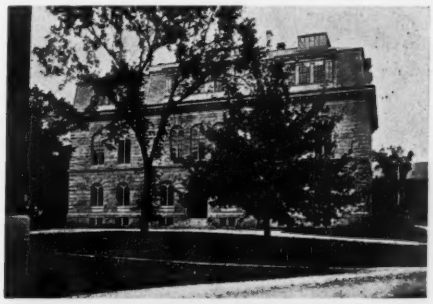
During this period chemistry does not appear as a study separate from physics, but various Harvard graduates made a name in it. Nathaniel White, A.B. 1646, became known for his work in chemistry and alchemy, as did Gershom Bulkeley, A.B. 1655, "eminent for his skill in chemistry," as well as in medicine and alchemy. George Starkey (Stirk), A.B. 1646, practiced the science in Europe and was a friend of Robert Boyle.

Changes and progress in course offerings frequently have a direct connection with faculty personnel, and the development of Harvard science shows many examples of this. The Hollis Professorship in Mathematics and Natural Philosophy was endowed in 1726 from the estate of Thomas Hollis (1659–1731), who also donated library books and scientific apparatus; the first appointee to it was Isaac Greenwood (from 1727 to 1738), and one of the most famous holders was John Winthrop (1714–1779), A.B. 1732, who was appointed in 1738. During his tenure Holden Chapel (the Harvard science building at a later time) was built (1744), and there occurred the disastrous Harvard Hall fire

(January 25, 1764). In this fire Harvard lost a fine building (the predecessor of the present Harvard Hall), the library and all the scientific apparatus (equipment for demonstrations in mechanics, hydrostatics, pneumatics, and astronomy). The Colonial Government replaced the building, and the other losses were partially made up by donations from alumni and friends. Among the larger contributors were a later Thomas Hollis (England), John Hancock, and Benjamin Franklin, who supplied some valuable apparatus. The "Donations Book" did not itemize Franklin's gifts, but it is quite certain that there were included two large static electricity machines and a vacuum pump, which are still preserved by the Harvard Physics Department. John Winthrop died in 1779; later Hollis Professors have been Samuel Williams (during 1780 to 1788), Samuel Webber (1789 to 1806, when he was chosen President), John Farrar (1807 to 1836), Joseph Lovering (1838 to 1888), B. O. Pierce (1888 to 1914), W. C. Sabine (1914 to 1919), Theodore Lyman (1921 to 1926), and Percy W. Bridgman (1926 to date).

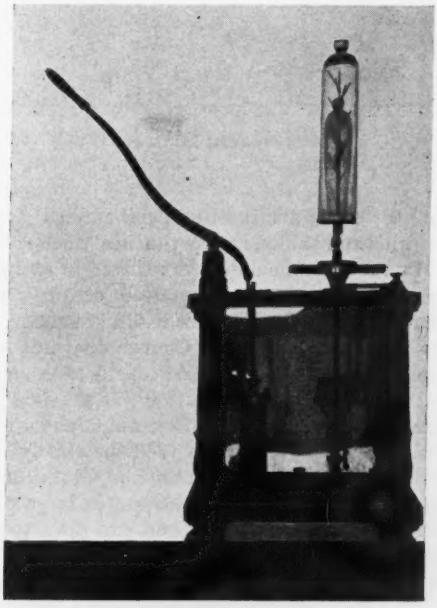
As the eighteenth century neared its end, the desirability of providing medical education became evident, and the Harvard Medical School began to come into being. The study of chemistry was a necessary part of a medical education, and a Professor of Chemistry and Materia Medica was appointed in 1783. This professor was Dr. Aaron Dexter, and he was the chosen man when, in 1791, the Erving Professorship of Chemistry and Materia Medica was endowed by the bequest of Major William Erving. This instruction in chemistry, unfortunately, was only for the medical school men, and students in the College could not take it except as extra work. Soon after 1800 the Commonwealth of Massachusetts put up a Medical Building in Boston, to which most of the work was transferred. A certain amount of the more elementary medical school instruction was continued in Cambridge (probably because of joint faculty limitations) and the rooms in Holden Chapel were converted to lecture and demonstration purposes in 1814. The Erving Professorship endowment was divided in 1816 to provide professorships in both medicine and chemistry; incumbents of the latter have been Aaron Dexter (1791 to 1816), John Gorham (1816 to 1827), John White Webster (1827 to 1850), Josiah Parsons Cooke, Jr. (1850 to 1894), Charles Loring Jackson (1894 to 1912), Theodore William Richards (1912 to 1928), and Arthur B. Lamb (1928 to date).

Benjamin Thompson (1753–1814), of Woburn, Massachusetts, was largely self-educated and worked in chemistry and engraving. Thompson's sympathies were with the British during the Revolution, and for this reason he fled to England in 1776; later he went to France and Bavaria, having achieved fame in natural science and mechanics, and was made Count Rumford of the Holy Roman Empire. Death ended Count Rumford's career in 1814, and in his will he left funds to establish at Harvard the Rumford Professorship and Lectureship on the Application of Sciences to the Useful Arts, which has been held since 1816 by Jacob Bigelow (1816 to 1827), vacant (1827 to 1834), Daniel Treadwell (1834 to 1845), Eben Norton Horsford (1847 to 1863), Oliver Wolcott Gibbs (1863 to 1887), John Trowbridge (1888 to 1910), Edwin H. Hall (1914 to 1921), and George W. Peirce (1921 to 1940). The memory of



BOYLSTON HALL

Horsford has been preserved in the Horsford Laboratory in the present Mallinckrodt Laboratory building, and that of Gibbs by the Wolcott Gibbs Memorial

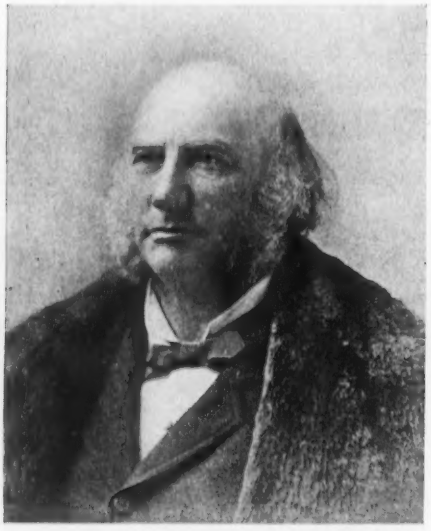


OLD VACUUM PUMP

Laboratory (1912) in which T. W. Richards carried out his later work.

Established curricula were hard to change during the nineteenth century, and even after 1800 we find Harvard men studying the old round of dead and classical

languages, logic, forensics and theology, a smattering of science, largely mathematics and physics, with a lone elementary course in chemistry. The science instruction was given in the time-honored synopsis plus lecture fashion with occasional desk demonstrations, by scholarly but old-fashioned teachers who often had been trained first for the ministry (Joseph Lovering, Hollis Professor for fifty years, being a conspicuous example). The rise of heavy industry and the engineering professions, however, soon changed all this, and

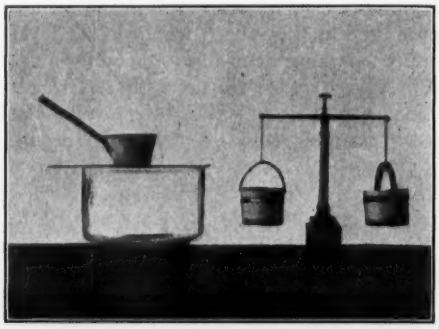


EBEN NORTON HORSFORD

brought to the Faculty European-trained teachers familiar with and skilled in experimental science.

For Harvard the machine age ushered in a vigorous, troubled, "trial-and-error" quarter century which, sadly enough, was not free from disagreement and a touch of personal discord. Course offerings in the sciences in the College expanded considerably, and the demand for engineering instruction was satisfied by the organization of the Lawrence Scientific School in 1847 (Lawrence Hall, 1849), and in 1866 the closely related and short-lived School of Mining and Practical Geology. Instruction in these schools was in large part by Harvard College Faculty men and was open to candidates who appeared properly qualified; many of the students already possessed degrees and thus imparted to the schools a graduate atmosphere and quality.

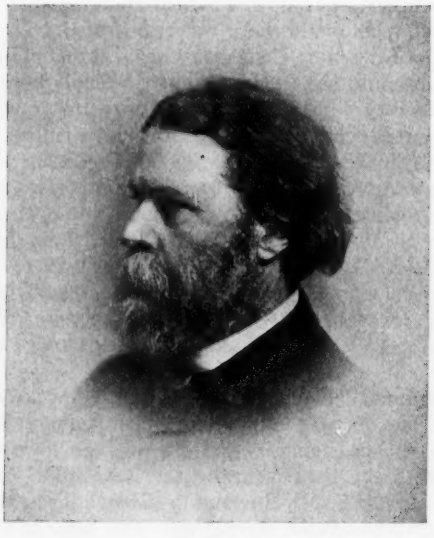
In the College, the course schedule for 1865–1866 lists science courses (including electives) for the four classes: Freshmen—algebra, geometry; Sophomores —trigonometry, navigation, surveying, analytical geometry, elementary chemistry, botany, physics; Juniors —physics, optics, astronomy, algebra, qualitative analysis; Seniors—optics, mechanics, calculus, geology, zoölogy. In the Lawrence Scientific School and the School of Mining and Practical Geology, general acquaintance with elementary sciences seems to have been a prerequisite for admission, and more advanced instruction (research for competent students) was given in chemistry by Wolcott Gibbs, zoölogy and geology by Louis Agassiz, engineering by Henry L. Eustis, botany by Asa Gray, anatomy and physiology by Jeffries Wyman, mathematics by Benjamin Peirce, mineralogy



DEMONSTRATION BALANCE TO SHOW RELATIVE DENSITIES OF GASES

by Josiah P. Cooke, geology by Josiah D. Whitney, and mining by Raphael Pumpelly.

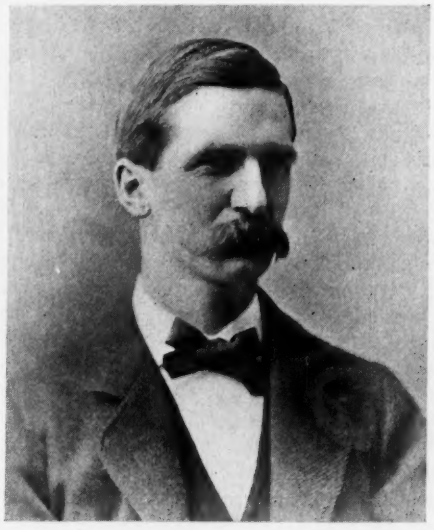
Fifteen years later (1881–1882) the College offering in chemistry consisted of descriptive chemistry, determinative mineralogy and lithology, qualitative analysis, quantitative analysis, the carbon compounds, advanced inorganic chemistry, and crystallography, all



WOLCOTT GIBBS

accompanied by laboratory work. The Lawrence Scientific School gave four-year courses in several major fields: "Civil and Topographical Engineering" with the degree of C.E., "Chemistry" with a B.S., "Mathematics, Physics and Astronomy" with a B.S., and "Natural History" with a B.S., these courses being designed and intended for professional men and teachers. The College also conferred the degrees of A.M., Ph.D., and Sc.D. on terms defined in the catalog (the latter two degrees having been instituted in 1872).

Almost from its inception the Lawrence Scientific School was the target of attacks, proposals, complaints, suggestions, and jealousy, both from within and without; nearly every President's Report to the Overseers from 1847 on contains some mention of discussions held, votes taken, or improvements desired. The fundamental difficulty seems to have been the problem of trying to give a traditional classical arts education leading to an old-fashioned A.B., in the immediate presence of a more intensive, specialized, practical professional curriculum (with academic competition in the near neighborhood). One of the earliest faults found was the fact that all too often students in one division could take courses in another division only by paying an extra fee above the regular tuition, or else not at all. This situation was remedied by vote of the Corporation in 1873 to permit free admission of students among the various departments, subject to competence and approval.



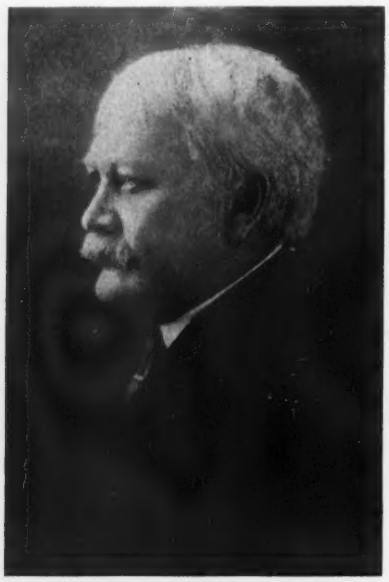
CHARLES LORING JACKSON

This lack of coördination and resulting duplication of instruction was partially, at least, responsible in an indirect fashion for an unpleasant situation which may have had a more concrete beginning as early as 1863 and came to a head in 1871. The principal figures in the matter were President Charles W. Eliot, Dr. Wolcott Gibbs, and Professor Josiah P. Cooke, Jr. In 1863 Eliot was Assistant Professor of Mathematics and Chemistry, had been in charge of much of the chemistry instruction in the Lawrence Scientific School,

HENRY BARKER HILL

and the Rumford Professorship had just been vacated by Eben N. Horsford. President Hill engaged Wolcott Gibbs as Rumford Professor instead of promoting young Assistant Professor Eliot, who then went to Europe to study, returned to teach, and in 1869 be chosen President of Harvard College. By 1871 President Eliot and the Corporation concluded officially that the chemistry instruction by Gibbs in the Lawrence Scientific School for the benefit of a dozen or so students was costing too much, relative to that in the College by Cooke for over seventy-five men, that the Scientific School work in Physics needed amplification, and that the Rumford Professorship had been intended as a purely physics appointment. Therefore (anticipating the spirit of the 1873 vote already mentioned) they voted to consolidate all chemical course instruction into Professor Cooke's department (Boylston Hall), and to expand physics instruction by increasing the laboratory work, space, and personnel in Harvard Hall, as well as requiring the Rumford Professor (Gibbs) to teach physics only (Gibbs had been giving a course in light and heat for some time). Professor Gibbs' research work and outstanding ability in chemistry was recognized (very inadequately) by providing him a private laboratory in Lawrence Hall. This is the official story from the President's Reports; the personal side has been mentioned by Dr. C. A. Browne in his admirable biography of the late Charles E. Munroe (A.B. 1871) recently published in the *Journal of the American*

Chemical Society (June, 1939). Munroe was assistant to Gibbs and later to Cooke and certainly was in a



CHARLES EDWARD MUNROE

position to know the strained relations between the two men, less so perhaps as regarded an Eliot–Cooke axis. Eliot had been a student of Cooke in college, studied under him later, and the 1863 appointment of Gibbs as Rumford Professor may well have rankled in the mind of Assistant Professor Eliot, just completing a five-year term and deservedly looking for promotion.

A subject agitated at intervals, inside and outside Harvard, was closer coöperation with or actual consolidation of Harvard engineering with Massachusetts Institute of Technology. One recurrence of the idea received official action by a Corporation vote (June 18, 1870) to invite discussion with the Government of the Institute. The ensuing conversations between the two committees concerned lasted on into the next winter, dealt with three consecutive proposals, and ended on February 22, 1871, in a meeting of the Technology committee which could not accept the last Harvard proposal and had no further one to make. Thus terminated officially an affair which caused considerable popular stir, especially among the alumni of the Institute.

Modern teaching methods have a dehumanizing tendency to forget that discoverers and teachers are in themselves vital and interesting beings. The rise of chemistry at Harvard was produced by and produced a number of men whose careers deserve brief mention.

Josiah Parsons Cooke, Jr., 1827–1894, A.B. 1848, was appointed Erving Professor of Chemistry and Mineralogy in 1850, and proceeded to install the experimental method of chemistry teaching in an inadequate basement space in University Hall; Boylston Hall, devoted to the sciences, was completed in 1857–1858, and to meet expansion was enlarged in 1871 by the addition of a mansard roof story. Cooke gave elementary chemistry for many years, as well as courses in mineralogy and crystallography, and published research papers on these subjects, inorganic chemistry, and atomic weight determinations. Professor Cooke used many desk demonstrations, often of his own invention. One of these, still used in "Chemistry A", is a simple but convincing device for showing the "heaviness" of carbon dioxide. It consists of a little knife-edge balance with cardboard buckets on the arms. Carbon dioxide is generated by acid and soda in a large covered jar and then is ladled out and poured into one bucket with an old tin dipper, causing that bucket to sag lower and lower. Another demonstration piece of Professor Cooke's period is a piston-type vacuum pump with a five-foot handle. The whole system is mounted in and on a massive wooden stand (carrying the name-plate of "E. S. Ritchie, Boston, Mass."), the vacuum being created and used in a variety of bell-jars placed on a plane metal base. Vacuum was a difficultly won and precious thing in the chemistry of threescore years ago, as well as appreciated by the assistant who operated the five-foot handle. The preparation, storage, and use of demonstration gases also was no simple problem.

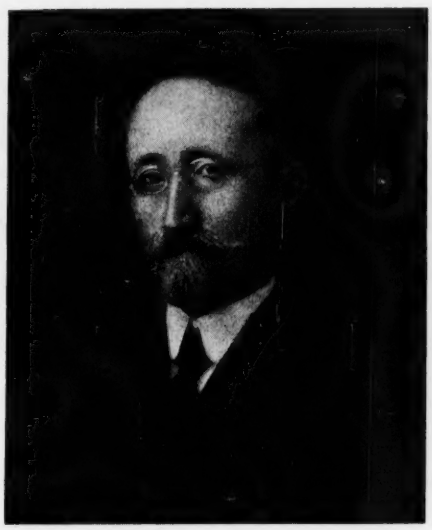
Eben Norton Horsford, 1818–1893, received the degree of Civil Engineer from Rensselaer Polytechnic Institute in 1837. After several years of teaching and engineering work, he went to Germany and studied with Liebig. On his return he was appointed Rumford Professor at Harvard in 1847. He carried out researches on various projects, usually of a practical type, and in particular on phosphate baking powders. In 1856 he founded the Rumford Chemical Works to manufacture baking powder, and in 1863 resigned his professorship to devote his time to the business.

Charles William Eliot, 1834–1929, A.B. 1853, took mathematics with Professor Cooke, after graduation studied chemistry under him, and in 1858 was appointed Assistant Professor of Mathematics and Chemistry for a five-year term, assisting Professor Horsford in the Lawrence Scientific School during 1861–1863. Eliot spent the two years 1863–1865 studying in Europe, and returned to teach chemistry at Massachusetts Institute of Technology (in Europe again in 1867–1868) until 1869 when he was chosen President of Harvard College, retiring in 1909.

Wolcott Gibbs, 1822–1908, was a graduate (1841) of Columbia College (now University), studied with Dr. Robert Hare in Philadelphia, and then at the College of Physicians and Surgeons in New York, receiving the M.D. in 1845, this being the only way possible of receiving instruction in chemistry. He then went to Europe, studying with Rammelsberg, H. Rose, Liebig, Laurent, Dumas, and Regnault. On returning he

taught for fourteen years in the Free Academy (now the College of the City of New York). Gibbs was appointed Rumford Professor in 1863 and held this position, with the assignment change already mentioned, until his retirement in 1887. Gibbs was an outstanding chemist of his day, and published many papers in analytical and inorganic chemistry, especially on the cobaltammines.

Frank Wigglesworth Clarke, 1847–1931, S.B. 1867, did some graduate work with Gibbs, and then, after several short periods of employment, was for a time instructor at the University of Cincinnati, where he did

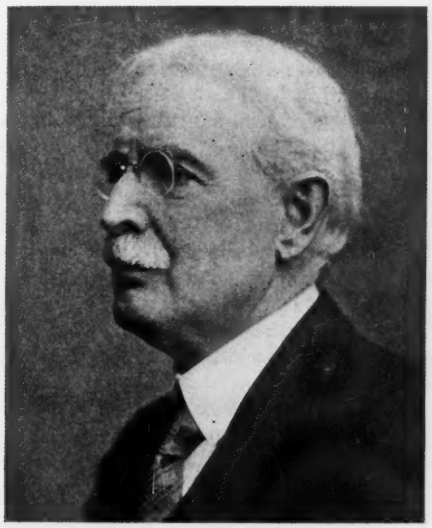


CHARLES ROBERT SANGER

research in minerals, their classification and analysis. This work led to his appointment as Chief Chemist of the United States Geological Survey in 1883, beginning a lifetime of service to the Government and science.

Charles Loring Jackson, 1847–1935, A.B. 1867, spent several years as assistant to Professor Cooke and then was appointed Assistant Professor in 1871. In 1873 he took a leave of absence and studied under Bunsen and then Hoffmann, with whom he worked in organic chemistry. He returned to Harvard in 1875, was promoted to Professor in 1881, and was Erving Professor from 1894 to 1912, when he retired because of ill health. During his long research career he published more than one hundred fifty papers, largely on the chemistry of the aromatic compounds.

Henry Barker Hill, 1849–1903, A.B. 1869, was a son of President Hill, and studied briefly in Germany, returning to Harvard in 1870 to teach organic chemistry and do research in it, particularly on furan derivatives and unsaturated aliphatic compounds. Hill succeeded Cooke as Director of the Laboratory and remained until his early death in 1903. Being Director involved slightly different problems from the present, since nearly all scientific apparatus and chemicals had to be imported from abroad, or made on the spot. There are still in storage in the Harvard Laboratory some relics dating back to this period, when vacuum pumps were imported, and the stock room help prepared the common acids by treating salts with sulfuric acid in earthenware Woulff bottles.



THEODORE WILLIAM RICHARDS

Charles Edward Munroe, 1849–1938, A.B. 1871, studied under, assisted, and retained the friendship of both Gibbs and Cooke. He was assistant in chemistry at Harvard until 1874, when he accepted a Professorship at the United States Naval Academy at Annapolis, and from 1886 to 1892 was located at the Torpedo Station in Newport, Rhode Island, where he organized the first general meeting of the American Chemical Society in 1891. In 1892 Munroe went to his final academic post at Columbian College (now George Washington University), Washington, D. C., where he retired in 1918 as Emeritus Professor, having made an international reputation as an expert in explosives and their chemistry. While a student at Harvard Munroe devised and perfected that useful and plebeian article, the clay filter cone, and later adapted the platinum Gooch crucible for direct filtering by installing a platinum sponge mat.

Harvey Washington Wiley, 1844–1930, S.B. 1873, came to Harvard with an M.D. in 1871 from Indiana Medical College. He became a good friend of Munroe, who tutored Wiley through three years of Harvard work and examinations in seventeen days. Wiley later taught at Purdue University and was Indiana State Chemist. In 1883 he entered the Government service as Chief Chemist of the Department of Agriculture.

His later career in food and legal chemistry is well known.

Charles Robert Sanger, 1860–1912, A.B. 1881, did graduate work in chemistry at Harvard, receiving the Ph.D. in 1884. After a short time as Assistant, he succeeded Charles E. Munroe at Annapolis (1886–1892), then spent seven years at Washington University in St. Louis, and returned to Harvard in 1899. He was Director of the Harvard Laboratory from 1903 until his death in 1912. Sanger's research was largely in the field of hygienic chemistry.

Theodore William Richards, 1868–1928, A.B. 1886, came to Harvard in 1885 with a degree from Haverford College, and proceeded to earn the A.B. in 1886, A.M. and Ph.D. in 1888, under the direction of Professor Cooke. He then went to Europe to study for a year, and returned to Harvard in 1889 as Assistant in Chemistry, reaching the rank of Professor in 1901. Richards' long years of research in precise measurements led to the development of many ingenious methods and useful articles or devices. Of these, the "bottling apparatus" and "nephelometer" (with Roger C. Wells) are among the earliest and best known.

ACKNOWLEDGMENTS

Many sources have been drawn upon in preparing this account, especially Peirce's "History of Harvard," Quincy's "History of Harvard," Vaille and Clark's "Harvard Book," the various exhaustively documented treatises by Professor Samuel E. Morison, Winsor's "Memorial History of Boston," several obituary notices in the *Proceedings of the American Academy of Arts and Sciences*, the article by Professor N. H. Black in the *Harvard Alumni Bulletin* for March 24, 1933, C. A. Browne's "Biography of Charles Edward Munroe" (*J. Am. Chem. Soc.*, **61**, 1301–10 (June, 1939)), and various volumes of the Harvard "President's Reports," "Annual Catalogs," and the "Gazette." The writer also is indebted to members of the staff of Widener Library, the Physics Laboratories, and the Chemical Laboratories, especially the late John H. Harrington of the latter, for information and help in preparing the illustrations. The portraits of Lovering, Cooke, Horsford, Gibbs, Hill, Jackson, Sanger, and Richards are reproduced from originals in the Harvard Archives (Widener Library); that of John Winthrop from Winsor's "Memorial History," Munroe from the Browne obituary article whic hhas been cited, and the Franklin Static Machine from the *Harvard Alumni Bulletin*.

NORRIS WATSON RAKESTRAW

CHARLES A. KRAUS

Brown University, Providence, Rhode Island

THE next issue of the JOURNAL OF CHEMICAL EDUCATION will be the first to appear under the editorship of Professor Norris W. Rakestraw of Brown University. When Dr. Otto Reinmuth tendered his resignation, he presented the Board of Publication with the problem of finding as his successor a man who could maintain the JOURNAL in the distinguished position which it has come to occupy under his able leadership. The choice of Dr. Rakestraw was the logical solution. He has been associated with the Division of Chemical Education since its establishment and during the period 1933–1939 served as its Secretary. In recent years he has been a member of the Board of Publication of the JOURNAL and, since last year, Assistant Editor. One can think of few persons who combine so well as Dr. Rakestraw the various qualifications of a successful editor—geniality, sense of humor, keenness of perception, decisiveness, energy, power of expression, and familiarity with the subject matter.

The second son of Edwin and Clara (Norris) Rakestraw, Norris Rakestraw was born in Toledo, Ohio, in January, 1895. He received his early education in the Toledo city schools and was graduated from the Toledo High School in 1912. While an undergraduate at Leland Stanford Junior University, he achieved unusual scholastic attainments and when in 1916 he received his Bachelor's degree, he was already a member of Phi Beta Kappa, Sigma Xi, and Phi Lambda Upsilon. During his undergraduate days, he was an outstanding member of the Stanford Gym Club and a star diver on the swimming team. After receiving his Master's degree the next year, he enlisted in the Chemical Warfare Service and spent eight months at the Edgewood Arsenal. He then returned to Stanford as an instructor and was awarded the Doctor's degree in 1921, having worked under Professor Robert E. Swain on the problem, "Chemical Factors in Fatigue." His early papers reflect his interest in athletics, being concerned with the effects of strenuous muscular exercise upon the concentrations of common blood constituents and, characteristically, the effects of loss of sleep. In many of these experiments, he was his own guinea pig. An interesting offshoot of these interests

is his work on the "body fluids of the sea-lion," the investigation of which involved a combination of travel, exercise, and chemical analyses, activities which still characterize his research.

During the next two years, he held teaching positions at Stanford and the California State Teachers College at San Jose. Subsequent to 1923, he spent nearly two years in the East and in Europe, studying at Yale, Cambridge, and the University of Copenhagen, with shorter visits to the principal universities of Great Britain, Scandinavia, Germany, France, and Switzerland. He spent the year 1925–26 at Oberlin College as assistant professor and the following year came to Brown as assistant professor to take charge of the work in beginning chemistry. Each summer finds him at the Woods Hole Oceanographic Institution where as a Research Associate he directs the work on the chemistry of sea water. One of his accomplishments, acquired under conditions which would hospitalize a less determined man, is the ability to titrate in the rocking laboratory of the auxiliary ketch, "Atlantis," while suffering from mal de mer.

In 1933–34, while on Sabbatical leave, he visited most of the oceanographic stations of the world—at the University of Washington, Scripps Institute at La Jolla, Hopkins Marine Station at Pacific Grove, Marine Laboratories at Naples, and the famous laboratory at Monaco. After this, with characteristic disregard for time and space, he made a rapid swing throughout western Europe to visit stations on the North Sea and the Baltic, especially at Keil, Hamburg, Copenhagen, Helsingfors, Oslo, and Bergen, the Marine Biological Laboratory at Plymouth, England, and laboratories in Iceland. If one designates attendance at the Florida meeting in April and the Cleveland meeting in September as the starting and stopping times for this itinerary, and remembers that this was before the days of transoceanic clipper ships, he obtains a fair sample of the startling amount of getting about which Dr. Rakestraw can accomplish in a few months. He still takes stairs two steps at a time, plays baseball or football at Chemistry Club picnics and accompanies the swimming team to Florida during the Christmas recess. In his early days in California he aroused the countryside with his side-car motorcycle; in New England his automobiles travel 100,000 miles in the shortest possible time; and now he may be expected to drop down almost anywhere in search of a manuscript, as he is piloting his own plane.

Dr. Rakestraw's command of his subject, his ready wit, his varied experience and his sympathetic understanding of his students and their problems have contributed to make him one of the outstanding teachers of elementary chemistry in this country. According to his philosophy of teaching, "education is self-education," and the incoming student soon learns that a knowledge of chemistry can be gained only through persistent, personal inquiry. While an apostle of hard work, Dr. Rakestraw never fails to lighten the apparent load by arousing the student's interest in the work he has to perform. We may confidently expect Dr. Rakestraw to attack the editorial problems of the JOURNAL OF CHEMICAL EDUCATION with the same enthusiasm and energy which have characterized all his undertakings heretofore.

SOME ILLUSTRATIONS *of* REACTIONS *between* SOLIDS

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THE old adage that solids do not react, as embodied in Aristotle's statement, "*Corpora non agunt nisi fluida*," has hampered progress in the chemistry of solids till well into the twentieth century. The systematic study of reactions between solids goes back to the work of Spring[1] on the effect of pressure on chemical reactions and that of Sir Roberts-Austen[2] on the diffusion of gold in lead at different temperatures. An intensive inquiry into the behavior of metals and alloys, inaugurated around the turn of the century, showed that reactions in solid alloys are of quite common occurrence. In 1909 Masing,[3] working in Tammann's laboratory, found that compressed metal filings reacted at temperatures below those of "eutectic" mixtures. It was soon recognized that pressure as such merely serves to bring the reacting substances in close contact.

Research on solid non-metallic substances started around 1910 with the work of Cobb[4] who heated mixtures of calcium carbonate and silica, calcium sulfate

[1] *Z. physik. Chem.*, **15**, 65 (1894).
[2] *Proc. Roy. Soc.* (London), **59**, 283 (1896); *ibid.*, **67**, 101 (1900).
[3] *Z. anorg. Chem.*, **62**, 265 (1909).
[4] *J. Soc. Chem. Ind.* (London), **29**, 69, 250, 335, 399 (1910).

and silica, and calcium carbonate and alumina at temperatures between 800° and 1000°. These substances interacted without the formation of liquid phases. Cobb assumed, however, that the solid particles were surrounded by what he called "quasi-vaporous" films which facilitated effective molecular contact with neighboring particles.[5] Recently Taradoire[6] carried out some low-temperature experiments in closed evacuated tubes and concluded "that a necessary but insufficient condition for reactions between solids is obtained when one of the reactants has a vapor pressure." Although it is true that the materials that Cobb used decomposed with the escape of gases, Hedvall,[7] in 1912 and subsequent years, has demonstrated that nickel oxide and cobalt oxide react with alumina, magnesia, and stannic oxide, forming either solid solutions or compounds at temperatures which exclude the existence of appreciable vapor pressures. In the industries reactions in the solid state have been carried out for years without attracting much attention on the part of scientists. Metallurgists have long been familiar with the process of "malleablizing" in which cementite (Fe_3C) is converted into iron and graphite. Another process, known as case-hardening, in which carbon dissolves in γ-iron with the subsequent formation on cooling, of cementite and α-iron, was the subject of a recent investigation by Tammann and Schönert.[8] There are also indications that a number of ceramic fireproof pigments used by the ancients were obtained by the dry method.

The whole subject of reactivity in the solid state has been reviewed recently by a Swedish author Hedvall,[9] who has devoted over thirty years to this branch of chemistry. It was a matter of surprise to the writer to find among over five hundred names in the index of Hedvall's book scarcely three dozen English and American authors. Most of the work on solids has evidently been carried out by continental workers, among whom, besides Hedvall, may be quoted Fischbeck, Hüttig, Jander, Jost, Seith, Tammann and Tubandt.

Nearly all the work mentioned in the literature has been done on the interaction of metallic oxides with other oxides or with salts (halides, sulfides, silicates, and so forth). There are some examples of double decomposition of salts, *e. g.*, the formation of mercuric iodide from potassium iodide and mercuric chloride. This is usually shown by pulverizing the dry mixture in a mortar and is sometimes erroneously represented as showing the effect of pressure on the speed of chemical reactions.[10] Likewise, potassium iodide will react easily with lead chloride. Instead of using a mortar and pestle, one may heat the dry mixture gently over a small flame. A number of other reactions which may be classed as double decompositions and are suitable for demonstration purposes, can readily be performed. In order to follow the course of the reaction one may take a pronounced change in color as proof that the reaction is proceeding at a perceptible rate. As a guiding principle for choosing the proper combinations, we may look up the heats of formation of the reactants and of the resultants. If the sum of the former is less than the sum of the latter, the reaction is likely to proceed. This is, of course, not a very reliable criterion, but may serve for want of a better one. Chemical thermodynamics teaches us that we should compare the free energies (ΔF) of the substances involved in the reaction and not the heats of formation ($-\Delta H$). There are, however, very few data for ΔF of solids available, and in case they can be found, we frequently do not know what their values are at higher temperatures. Ordinarily the values for ΔF and ΔH reported in the literature for anhydrous solids (at 25°) are not far apart, as is seen from the following list.[11]

TABLE 1

	ΔF *in cal.*	ΔH *in cal.*		ΔF *in cal.*	ΔH *in cal.*
AgCl	−26,220	−30,300	$ZnCl_2$	−88,260	−99,280
AgBr	−22,900	−23,810	$ZnBr_2$	−74,090	−78,230
AgI	−15,810	−15,170	ZnI_2	−49,930	−50,505
			$CdBr_2$	−70,270	−75,390

As an example, let us consider the reaction:

$$\underset{22.2}{PbS\ (black)} + \underset{218.0}{CdSO_4\ (white)} < \underset{216.2}{PbSO_4\ (white)} + \underset{33.9}{CdS\ (yellow)}$$

From the values of the heats of formation[12] we may infer that the reaction will proceed from left to right, a conclusion which is sustained by experimental evidence. Commercial lead sulfide usually contains a small amount of sulfur which is expelled by heating. The dry cadmium sulfate is obtained by heating the hydrated salt $CdSO_4 \cdot {}^8/_3H_2O$. The lead sulfide is placed at the bottom of a test-tube and compressed to a layer of about one inch deep. On top of this is placed an intimate mixture of lead sulfide and cadmium sulfate (dull gray in appearance) and this layer in turn is covered with a one-inch layer of cadmium sulfate. On revolving the test-tube over the flame of a Bunsen burner the middle layer will assume a yellowish hue, due to the formation of cadmium sulfide. For comparison, a tube containing dried lead sulfate and cadmium sulfide with an intermediate mixture of the two undergoes no change except for a darkening of the cadmium sulfide on heating. On cooling it resumes its light color.

The following reactions, all performed in a similar manner, may likewise be used for demonstration purposes

[5] *J. Soc. Chem. Ind.* (London), **29**, 336 (1910).
[6] *Bull. Soc. Chim.*, **6**, 866, 1249 (1939).
[7] *Ber.*, **45**, 2095 (1912); *Z. anorg. allgem. Chem.*, **86**, 201, 296 (1914).
[8] *Z. anorg. allgem. Chem.*, **122**, 27 (1922).
[9] HEDVALL, "Reaktionsfähigkeit fester Stoffe," J. A. Barth, Leipzig, **1938**.
[10] *Cf.*, VAN KLOOSTER, "Lecture demonstrations," 2nd ed., Easton, Pa., **1925**, p. 58.
[11] BATES, *J. Am. Chem. Soc.*, **61**, 1040 (1939).
[12] In kcal., *Cf.*, LANGE, "Handbook of Chemistry," 3rd ed., Handbook Publishers, Sandusky, Ohio, **1939**.

$$\begin{array}{lcl} K_2S\ (grayish) + CdSO_4 & = & CdS + K_2SO_4 \\ 87.1 + 218.0 & < & 33.9 + 338.6 \\ K_2S + Ag_2SO_4 & = & Ag_2S + K_2SO_4 \\ 87.1 + 96.2 & < & 5.0 + 338.6 \end{array}$$

Of these six salts potassium sulfide has the lowest melting point (471°). Care should be exercised, therefore, to avoid a possible partial melting.

The two salt pairs mentioned previously

$$\begin{array}{lcl} PbCl_2 + 2KI & = & PbI_2 + 2KCl \\ 83.9 + (2 \times 78.8) & < & 41.8 + (2 \times 104.3) \\ HgCl_2 + 2KI & = & HIg_2 + 2KCl \\ 53.3 + (2 \times 78.8) & < & 25.2 + (2 \times 104.3) \end{array}$$

which contain halides of heavy metals with rather low melting points should not be heated over 100° in order to prevent partial fusion.

Anhydrous cobalt sulfate which shows a reddish pink color will turn to a bluish purple when heated with sodium chloride. The cobalt chloride which is formed does not melt but sublimes and is said to "boil" at 1049°.

$$\begin{array}{l} CoSO_4 + 2NaCl = CoCl_2 + Na_2SO_4 \\ (\ ?\ + 2 \times 78.8)\ (95\ + 328.6) \end{array}$$

Finally it may be well to indicate at this point some possible industrial applications of reactions in the solid state. Zinc and cadmium lithopone are usually prepared by the wet process. Judging from the heats of reaction of the dry compounds in the reactions

$$\begin{array}{lcl} BaS + ZnSO_4 & = & BaSO_4 + ZnS \\ 102.5 + 229.6 & < & 340.2 + 41.3 \\ BaS + CdSO_4 & = & BaSO_4 + CdS \\ 102.5 + 218.0 & < & 340.2 + 33.9 \end{array}$$

it might be inferred that these lithopones are obtainable by heating the mixture of reactants in the dry state. When a commercial grade of (previously ignited) barium sulfide was mixed with anhydrous cadmium sulfate, an ochre-colored product was obtained. This retained the same color in petrolic ether but on shaking the mixture with water, a yellow powder settled out which matched the color of a commercial sample of cadmium lithopone suspended in water. These examples are only a few of numerous possible combinations that might be tried to test the usefulness of reactions in the solid state. The technic of mixing, heating, and analyzing the resulting products obviously differs from case to case and offers promising results in a field that has, up till now, not been cultivated intensively on this side of the Atlantic.

NEGLECTED TYPES *of* EXAMINATIONS

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TO MANY teachers of general chemistry the title of this paper may seem ambiguous but according to the author's observations the types of examinations described here have been neglected. We do not lay claim to anything strikingly original; the purpose of the paper is chiefly to call attention to a useful and practical procedure. The types of examinations we wish to describe are, I. Open-book lecture examination; II. Open-book laboratory examination; and III. Practical laboratory examination.

I. THE OPEN-BOOK LECTURE EXAMINATION

The administration of the so-called open-book lecture test introduces some obvious difficulties. In fairness to all students the sources of reference must be restricted. One procedure is to allow each student the use of texts regularly assigned for the course and any personal notes he wishes to bring. At the outset one is faced with the problem of phrasing questions which are not directly answered in the available texts. Questions based directly on textbook material can serve a useful purpose. The student should be made aware of the apparent necessity of the appendix, and, above all, of the usefulness of an index. The latter might be considered more seriously by some textbook authors. We have observed the amazing helplessness of some otherwise apparently good student when faced with an open-book examination. Reverse the picture and imagine the teacher, or the practicing chemist, suddenly deprived of his sources of reference when faced with the solution of a chemical situation. A certain store of factual information must be available for any eventuality, to be sure, but why not test the student during his training period in somewhat the same way in which he will be tried later? Our attempt to continue the teaching process in general chemistry while testing the student may be illustrated most easily by displaying a few typical questions. We must hasten to point out that the students are forewarned and even cautioned that the open-book test period is not a study period—the books are available for quick reference only.

Typical open-book questions we have used in general chemistry are given.

(1) Underline the symbol or formula of the substance in each series having the characteristics called for.

(*a*) Lowest concentration of H^+: 0.1*N*, $HC_2H_3O_2$, 0.1*N* H_2SO_4, 0.1*N* HCN.
(*b*) Turns blue litmus paper to red: 0.1*N* Na_2CO_3, 0.1*N* $AlCl_3$, 0.1*N* NaCl.
(*c*) Least soluble in water (18°C.): NaCl, $(NH_4)_2SO_4$, $BaSO_4$, $CaCl_2$.
(*d*) Most soluble in a solution of NaOH: $Cd(OH)_2$, $Fe(OH)_3$, $Al(OH)_3$.
(*e*) Highest atomic number: N, W, O, Re.
(*f*) Largest number of planetary electrons: Na, S, Cl, Al.

(2) Calculate the formula weight of $(NH_4)_2Cr_2O_7$.
(3) Calculate the per cent. composition of Na_2CO_3.
(4) From a study of the solubility curve in your text estimate the solubility of: (*a*) KNO_3 at 50°C.; (*b*) KCl at 30°C.; (*c*) $K_2Cr_2O_7$ at 70°C.
(5) From the density value of NO show how to calculate its G.M.W.
(6) Give the formula of the reagent that will dissolve.
(*a*) $Zn(OH)_2$, but not $Cd(OH)_2$.
(*b*) SnS_2, but not SnS.
(*c*) Ag, but not Pt.
(*d*) $BaCO_3$, but not $BaSO_4$.
(7) The following reagents only are available: $Ba(OH)_2$, $K_2Cr_2O_7$, FeS, Zn, P, $CuSO_4$, H_2O, HCl, NH_4OH, KI, S, I, H_2SO_4. Write equations showing how you would proceed to prepare: (*a*) lithopone; (*b*) cuprous iodide; (*c*) hydrogen iodide.
(8) The following metals and solutions are available: Cd, Ag, *N* $CdSO_4$, *N* Ag_2SO_4. (*a*) Sketch a primary cell. (*b*) Calculate the voltage of the cell.
(9) When 4.6 grams of the hydrate of sodium sulfate were heated to constant weight, 2.57 grams were driven off as water vapor. Determine the formula of the hydrate.
(10) In what part of the periodic table would you look for the elements having the characteristics indicated?
(*a*) Form the most stable hydrides.
(*b*) Form the most basic hydroxides.
(*c*) Show the lowest degree of chemical activity.

Thus in Questions 1*a* and 1*b*, the student discovers the usefulness of the Ionization Table in his text. In 1*c* the Solubility Table, in 2, 3, and 9, the Atomic Weight Table, in 5 the Density Table, in 10 the Periodic Table, and 8 the Table of Potentials come into use. Question 4 requires an understanding of the graphical representation of solubility. The other questions may call into use the laboratory manual and the index of the text. Numerical problems are perhaps among the most easily adapted to the open-book form of test.

II. OPEN-BOOK LABORATORY EXAMINATION

In this test the student may be permitted to use his own laboratory notes and to observe his own locker, chemical kit, and the supplied chemicals and equipment upon which the test is based. It is not necessary to call attention to the waste of energy in grading laboratory notebooks. Why waste time and energy policing note-writing and why outlaw occasional quiet conferences of adjacent students when the results may be determined through tests based on student observations and records? If the notes fail to be useful to the student, certainly they are worthless to the instructor for class record, no matter how neatly and completely the notes may be written. It is important to teach the laboratory student that he, like the true student of science, should record his observations specifically for his own use. This does not mean that the instructor should ignore note-writing by his students; on the contrary, he should give the student the benefit of his experience in effective recording of observations. The notebooks should never be graded seriously. The laboratory open-book test should determine how well the student can use his notes in recalling exactly what he observed. If the student can be convinced that he will be examined thus, he will try seriously to record his observations in a manner most useful to himself and not for the instructor to grade. The points of view are distinctly different. A student with this more wholesome point of view is not so apt to be satisfied with beautiful paper reactions—he will want to see the chemicals in action. A first open-book test is usually necessary, however, to convince the average student that the instructor really means that he should write the laboratory notes for his own consumption. Unless the student is given a real urge to test for himself reactions which appear so easy in the textbook or on the lecture table, he will leave the course with a sadly distorted idea of this experimental science.

A few typical questions will illustrate the form of test suggested above.

(1) Determine the zero point of a balance that gave the following readings: 8.5 *L*, 5.6 *R*, 7.9 *L*, 5.0 *R*, 7.3 *L*.
(2) Make a labeled sketch of a charged drying tube.
(3) Make a sketch of a Bunsen flame. Indicate by a cross the hottest part of the flame. Cross-hatch the coolest part.
(4) Describe in detail what you observed when you added concentrated sulfuric acid to sucrose.
(5) Manual, page 16. Underline the compound in each group which gave off oxygen most readily under the conditions of the experiment: (*a*) mercuric oxide and manganese dioxide; (*b*) lead dioxide and potassium chlorate.
(6) State the numbers and weights of your numbered metal strips.
(7) From your experiments with the following pairs of solutions state what you observed when (illustrate with chemical equations)
(*a*) An excess of stannous chloride was added by drops to mercuric chloride;
(*b*) Ammonium hydroxide was added in like manner to cupric chloride.
(8) Under observations state what you heard, saw, and smelled.

Substance	Treatment	Observations
0.01*N* HCl	Drops of methyl violet	
0.5*M* NaCl	"Chlorine water"	
0.1*M* $Na_2S_2O_3$	3*N* HCl	
Saturated solution SO_2	H_2S	
As_2S_3	Solution $(NH_4)_2S$	
0.2*M* $CrCl_3$	3*N* NaOH excess	
0.2*M* Na_2CO_3	0.3*M* $Al_2(SO_4)_3$	
0.2*M* $ZnCl_2$	Drops of 3*N* NaOH	
5 cc. 0.1*N* $AgNO_3$ + 1 cc. 1 per cent. gelatin	1.5*N* NaBr	

The complete and direct answers to these questions, as a rule, cannot be found in the textbook. The physically lazy student who has not performed the experiments thoughtfully quickly discovers the futility

of his usual technic. Close observation of the students at work suggests questions which determine progress for student as well as for the instructor.

III. PRACTICAL LABORATORY TEST

The student is provided with limited chemicals and apparatus with which to perform a short experiment, or is required to make a critical study of a definite "set-up." The mechanical arrangement found quite workable is as follows: (*a*) the laboratory is divided into twenty-five numbered stations; (*b*) at each station is arranged a typical "set-up" or a set of chemicals and apparatus; (*c*) a typed card is placed at each station stating the purpose, procedure, and information sought; and (*d*) each student is provided with a sheet with twenty-five numbered spaces for statements concerning each experiment of corresponding number. Two or three minutes are allowed for each experiment, and at a given signal the student moves to the next station in an orderly manner until the twenty-five experiments have been completed. The character of the test cited here can be illustrated by giving descriptions of several typical stations. The statements appearing in small type constitute the copy made available on the card to the student.

(1) Summing up weights. Balance, crucible, and weights.

(1) The balance has been adjusted to its zero point. Record the weight of the crucible.

(2) The flame. Burner. Mounted platinum wires, *A* and *B*.

(2) Which wire, *A* or *B*, is in the hottest part of the flame?

(3) Pieces of apparatus labeled *A*, *B*, *C*, and so forth.

(3) Name each piece of apparatus.

(4) Gas Laws. Inverted 200-cc. bottle mounted in filled sink or trough.

(4) Is the gas pressure in the bottle greater or less than the barometric pressure?

(5) Gas laws "set-up." Meter rule.

(5) The barometric pressure today is 768.7 mm. What is the pressure of the gas in the eudiometer?

(6) Colored solution—(1) Cu^{++}; (2) Cr_2O_7''; (3) MnO_4'; etc.

(6) The solution in each vial owes its color to a well-known ion. Identify each by number and formula of the ion.

(7) Odor test. NH_4OH, SO_2, H_2S, and so forth.

(7) Sniff cautiously. Identify each substance by number and formula.

(8) Fifty-cc. graduated cylinder, 100-cc. beaker, narrow bottle with mark at about 37-cc. level.

(8) How much water will the bottle hold up to the mark?

(9) A large scale temperature-vapor pressure curve mounted on card board.

(9) According to weather bureau reports, barometric pressure on Mt. McKinley (elevation 20,300 ft.) is 415 mm. What is the boiling point of distilled water at that location?

(10) Test solutions: *N* Na_2CO_3; *N* $ZnCl_2$. Indicator: Methyl orange. Vials and droppers.

(10) Unknown solutions may be *N* Na_2CO_3 or *N* $ZnCl_2$. Add one drop of methyl orange to a dropper of each test solution. Identify each by number and formula.

(11) Solubility of salts. Bottle of powdered gypsum and bottle of sodium chloride. Spatulas and test-tubes.

(11) Which salt is least soluble in water, *A* or *B*?

(12) Neutralization. Two burets, standard solutions of an acid and a base, indicators, and flask.

(12) Before titation both burets *A* and *B* were filled to the zero mark. The volumes drawn off were required for neutralization. The acid in buret *A*, is 0.2*N*. Calculate the normality of the base in *B*.

(13) Successive tests. Test solution: $HgNO_3$. Reagents: (*a*) NaCl, (*b*) NH_4OH.

(13) To a dropper of the unknown add a dropper of reagent "*a*" and then a dropper of reagent "*b*." Record the formula of the ion indicated.

(14) Carbon dioxide apparatus. CuO and C in generator tube. Both tubes tightly stoppered.

(14) The black mixture in the generator is CuO and C. The solution is lime water. Criticize this apparatus for preparing and testing CO_2.

(15) Sulfur dioxide generator. End of safety tube above level of the liquid.

(15) Criticize this sulfur dioxide generator.

Observations made on many students taking this form of practical test indicate that the manipulations required seem to help some students overcome that all too common acquired ailment, the "examination fear." The author in some instances has found that students who fared poorly in the usual closed-book examination conquer their fears and do creditable work in the practical test. Glaring examples of the reverse order are not uncommon. Perhaps we can ponder what one student said as he handed in his practical test paper, "I feel that the answers in this paper are definitely my own."

In conclusion we must be mindful of the fact that the open-book or the practical laboratory form of test cannot be considered a complete testing procedure. In fact, it is very doubtful that any form of testing whether under the heading of the so-called "new type" or "old type" can be considered adequate. A large percentage of the good students will excel in any form of test but owing to some of the obvious evils of our systems of examining and grading many "good" or "fair" students fail to become rated in proportion to their actual capabilities. As long as grades are required we should in fairness to the variations in student temperament use various types of tests for each distinct purpose; we should always strive to make the test a part of the teaching process.

A SIMPLE APPARATUS *for* MEASURING *the* DIELECTRIC CONSTANT *of* NON-CONDUCTING LIQUIDS

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Two of the more interesting applications of dielectric constant data are the determination of the values of dipole moments and the detection of intermolecular formations in mixtures. The apparatus described is capable of investigating these fields with reasonable precision. Line drawings of wiring circuits of the receiver and oscillator are given. The heterodyne beat, between a broadcast carrier wave and waves from the oscillator, is employed to detect constant capacitance in the measuring circuit. The apparatus has been used quite successfully by students in an elementary physical chemistry laboratory. The dipole moment of nitrobenzene and the dielectric constant of ethyl ether-chloroform mixtures were determined. The results are in good agreement with accepted values. Operations during a measurement are shown to be extremely simple.

✦ ✦ ✦ ✦ ✦ ✦ ✦

THE increasing importance of a knowledge of dielectric constants of substances is evidenced by the large number of measurements that have appeared in recent literature. Several methods have been used in making these measurements, but probably the most precise are the methods based on the heterodyne beat principle.

In designing an apparatus for the measurement of the dielectric constants of liquids one must decide what range of constants are to be measured, and what the nature of the measured substances are, other than simply their dielectric property.[1] Since the present apparatus is designed for non-conducting liquids, it may be used for materials of dielectric constants within a range of 2 to 7.[2] This class of pure substances and solutions in which they are the solvents have been the most extensively investigated of all liquids. Dielectric constant data have a number of applications of which two of the more interesting are the detection of the presence of dipoles and the detection of the formation of intermolecular compounds. For details of the measurements of dipole moments reference may be made to an excellent elementary treatment given by Sidgwick.[3] Dole[4] and Mack and France[5] give good physical discussions of the matters involved. The measurement of the dipole moment is dependent on the Clausius-Mosotti relation with the interpretation Debye[6] has given it. The equation is

$$P = \frac{\epsilon - 1}{\epsilon + 2}\left(\frac{M}{d}\right) = \frac{4}{3}\pi N\left(\alpha + \frac{\mu^2}{3kT}\right)$$

In this equation P is the molar polarization, ϵ the dielectric constant, M the molecular weight, d the density, N the number of molecules per mole, α the polarizability, or the induced moment per molecule per unit field strength, μ the dipole moment, k the Boltzman energy constant, and T the absolute temperature.

The use of the dielectric constant in detecting intermolecular formations in liquids has been employed extensively by Earp and Glasstone.[7] Using evidence from dielectric constant measurements these authors find there is probably a hydrogen bonding between trihalogen methanes and such substances as ethers and ketones.

The purpose of the present paper is to describe an apparatus capable of investigating with moderate precision the two phases of study mentioned above, and to show some results that have been obtained. The apparatus is not presented as an instrument for precise measurements, but will certainly afford dielectric constant values of approximately one per cent. absolute, and one-half of one per cent. relative precision. Since the apparatus is used as an exploratory research tool, and in the laboratory of elementary physical chemistry,

[1] If the substances are conductors certain modifications of method must be made so that the results are not mixtures of several properties of the materials.

[2] GEMANT, "Liquid dielectrics," John Wiley & Sons, Inc., New York City, **1933**, pp. 1–9.

[3] SIDGWICK, "Covalent link in chemistry," Cornell University Press, Ithaca, New York, **1933**, Chap. V.

[4] DOLE, "Experimental and theoretical chemistry," McGraw-Hill Book Co., Inc., New York City, **1935**, Chaps. XI, XII.

[5] MACK AND FRANCE, "Laboratory manual of physical chemistry," 2nd ed., D. Van Nostrand Co., Inc., New York City, **1934**, pp. 208–16.

[6] DEBYE, "Polar molecules," The Chemical Catalog Co., New York City, **1929**, pp. 27–35.

[7] EARP AND GLASSTONE, *J. Chem. Soc.*, **1935**, 1709.

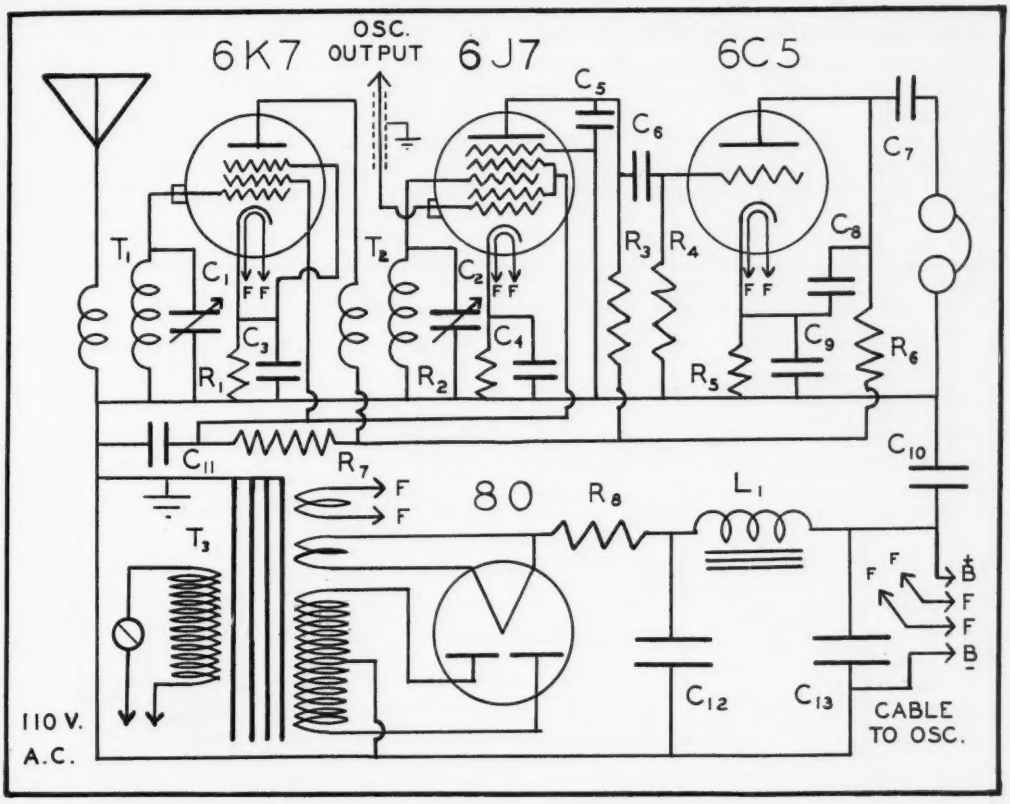

FIGURE 1.—WIRING DIAGRAM OF RECEIVER CIRCUIT

T_1, Meissner midget antenna coil, 150–550 meters, with 365 MMF. tuning condenser (Wholesale Radio Service Company No. K10046). T_2, Meissner midget R.F. coil to match T_1 (W. R. S. Co. No. K10047). T_3, Power transformer (W. R. S. Co. No. K5635). L_1, Filter choke 10 henries at 50 ma. Condensers as follows: C_1 and C_2—2 gang 365 MMF. tuning with trimmers; C_3 and C_4, 0.1 MFD. 200 v. tubular; C_5 and C_8, 500 MMF. mica; C_6 and C_7, 0.01 MFD. 400 v. tubular; C_9, C_{10} and C_{11}, 0.25 MFD. 400 v. tubular; C_{12} and C_{13}, 8 MFD. 550 v. dry electrolytic. Resistors as follows: R_1, 500 ohm, 1/2 watt; R_2, 400 ohm, 1/2 watt; R_3 and R_6, 100,000 ohm, 1 watt; R_4, 1 megohm, 1/2 watt; R_5, 3000 ohm, 1/2 watt; R_7, 25,000 ohm, 1 watt; R_8, 1000 ohm, 10 watt wire wound.

it is of sufficient precision. The condition of constant capacitance in the measuring circuit is detected by the beat note between a local broadcast station carrier wave, and oscillations generated by a variable oscillator. Otto and Wenzke[8] have used this principle with apparently excellent results. The condition of maintaining a constant capacitance in the measuring circuit is the most commonly used method in such measurements. The small receiver and variable oscillator are made from inexpensive parts which may be obtained from any of the wholesale radio houses. The total cost of all parts excluding assemblying time and a small amount of desirable but not necessary machine work is not greater than thirty-five dollars.

RECEIVER

The receiver consists of one stage of tuned radio frequency using an RCA 6K7, a converter stage using an RCA 6L7, and an audio stage using an RCA 6C5. The 6L7 is a multigrid tube and, in addition to its amplifying action, it serves as a mixer for the oscillations from the variable oscillator and the carrier wave. The beat note between the two oscillations is fed to the RCA 6C5 which amplifies the note to the audible range. The rectifier filter system is not elaborate as the presence of some alternating current hum in the receiver output is not objectionable. Figure 1 shows all wiring details of the receiver. The specifications on all parts are complete. The receiver was built on an old chassis; consequently many of the necessary holes were already bored. Such items are usually available at local radio repair shops. A great saving in time may be effected by having some person familiar with such work assemble the parts.

OSCILLATOR

The oscillator employed an RCA 6J7 in an "electron coupled" circuit. The screen grid is by-passed to ground and effectively shields the frequency determining portions of the tube. The alternating radio frequency current which reaches the plate affords a means

[8] OTTO AND WENZKE, *Ind. Eng. Chem., Anal. Ed.*, **6**, 187 (1934).

of coupling which leaves the frequency determining portion of the tube virtually independent of voltage, load, and disturbances in the plate circuit. The wiring diagram of the oscillator and specifications for its parts are given in Figure 2.

An essential feature of the oscillator is the National micrometer dial mounted integrally with the tuning condenser C_o. The condenser is a straight line capacity

If C_o is chosen as 220 MMF. and the parallel condenser the same, one may use the following specifications for the inductance if the tuning frequency is to be 1500 kilocycles. The coil should be close-wound on a fiber form 2.54 cm. diameter using 42 turns of No. 25 D.S.C. copper wire. The tap is made at twelve turns from one end. The entire oscillator assembly, excepting the measuring condenser, was mounted inside an aluminum

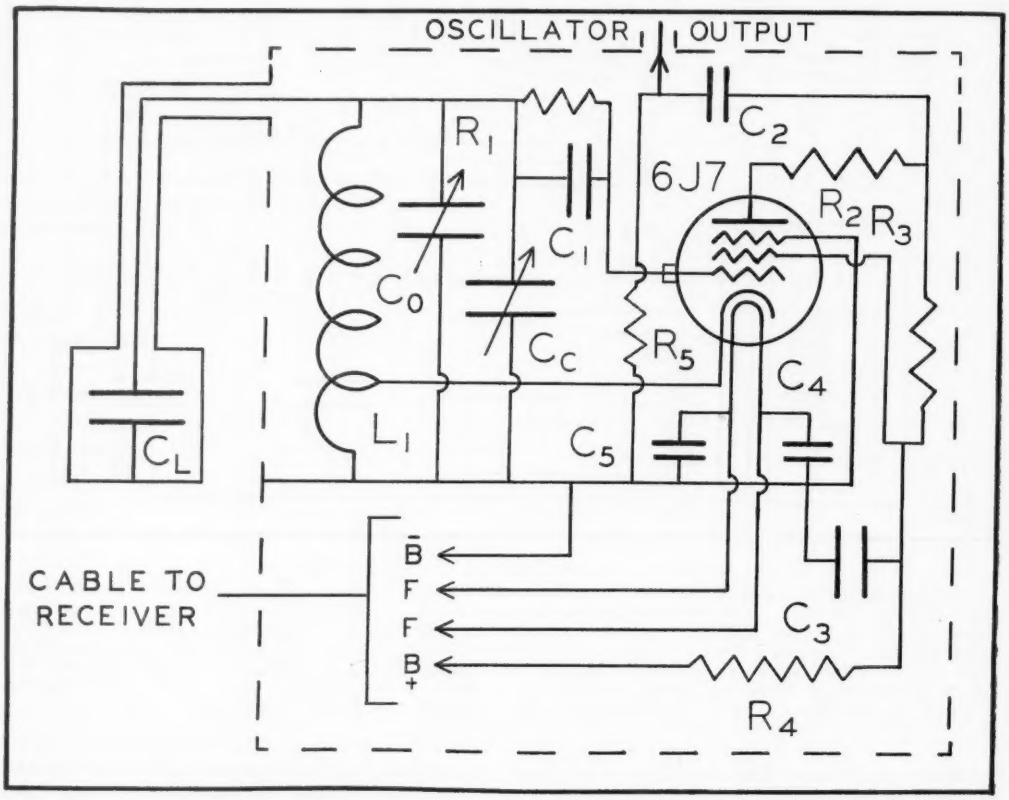

FIGURE 2.—WIRING DIAGRAM OF OSCILLATOR CIRCUIT

L_1, see text. Condensers as follows: C_L, 50 MMF. National transmitting type No. TMSA-50; C_O, Cardwell X T 220 P.S. transmitting type equipped with National "Micrometer" dial; C_c, Cardwell X T 220 P.S. transmitting type; C_1 and C_2, 100 MMF. mica; C_3, 0.1 MFD. 400 v. tubular; C_4 and C_5, 0.1 MFD. 200 v. tubular. Resistors as follows: R_1, 1 megohm, 1/2 watt; R_2, 8000 ohm, 1 watt; R_3, 20,000 ohm, 1 watt; R_4, 35,000 ohm, 1 watt; R_5, 350,000 ohm, 1 watt.

type, and in conjunction with the dial mechanism gives good linearity from 50 to 450 divisions of the dial, the scale of which extends from 0 to 500 divisions. The inductance L_1 was so adjusted that, with the measuring condenser C_L set at minimum capacitance, a beat note between the oscillator and the 1500 kilocycle carrier wave was obtained at a dial setting of C_o of about 450 divisions. This setting of C_o represents nearly its maximum capacitance. The necessity of critical adjustment of inductance L is obviated by employing a variable conpensating condenser in parallel with C_o. The compensating condenser is shown as C_c in Figure 2.

box ten inches by eight inches by seven inches with a one-sixteenth inch wall thickness.

MEASURING CONDENSER

The liquid condenser, C_L, was mounted on a circular brass plate one fourth of an inch thick. The ground lead from the oscillator, a five-eighth inch copper pipe, was soldered to this plate. The high potential lead was made by running a one-eight inch brass rod through holes in the center of polystyrene resin discs and placing this assembly inside of the five-eighth inch copper tube. The bottom and sides of C_L were made by cutting a

three and one-half inch section of three and one-half inch inside diameter brass pipe and soldering a plate on one end of the section. The other end of the pipe was drilled and threaded in three places so as to receive screws which passed through the top plate.[9] The shaft of the rotor extended up through the top plate, and to the shaft was attached a horizontal three-eighth inch square aluminum rod two and one-fourth inches long. Stops were arranged by means of studs screwed into the top plate. The arm could be stopped at intervals of 60°, 120°, or 180° rotation. This method enables one to make measurements with the maximum sensitivity allowed by the variable capacity in C_O. If the dielectric liquid has a large constant the rotation of C_L must be such that the change in capacity can be measured by changing C_O.

MEASUREMENT

The mechanics of a measurement are as follows. The rotation of C_L is fixed by proper placement of the studs. The allowable rotation is determined as previously indicated. The capacity change in moving C_L from its minimum to the final position is determined with air in C_L. The magnitude of the change in capacity is determined by setting C_L in its minimum position and finding the reading on C_O that gives the variable oscillator the same frequency as the carrier wave from the broadcast station. This condition is recognized by the absence of a heterodyne beat in the earphones if, with a slight change of C_O in either direction, a beat is heard. The arm of C_L is now moved to its maximum and then, to return to the carrier wave frequency, C_O must be changed to some new value. The difference between C_{Oa} and C_{Ob} measures the capacity change in C_L.[10] A measured volume of the liquid is now introduced, and the new value of the capacity change in C_L can be determined with the liquid present. The liquid volume should be sufficient to cover all parts of the measuring condenser proper. The dielectric constant is then given by (if air = 1):

$$\epsilon = \frac{\Delta C_O \text{ (liquid)}}{\Delta C_O \text{ (air)}}$$

This result will not be highly accurate, but even neglecting a calibration of C_O it is found to yield good results.

RESULTS

This method of measurement has been applied to mixtures of ethyl ether and chloroform and to the determination of the dipole moment of nitrobenzene in benzene. The results were obtained by students in an elementary physical chemistry laboratory. Table 1 shows the dielectric constant results of three students on the chloroform-ether mixtures.

TABLE 1

Mole fraction $CHCl_3$	*Students* *A*	*B*	*C*
0.00	4.34	4.33	4.29
0.40	5.76	5.78	5.66
0.55	5.93	5.86	5.82
0.80	5.61	5.52	5.53
1.00	4.80	4.80	4.79

The results have been corrected to 20°C. using the temperature coefficient found by Coop[11] for this mixture. The actual temperatures of the measurements were 27.8°C. for *A*, 23.0°C. for *B*, and 24.5°C. for *C*. The values obtained agree well with those found by Coop.[11] The materials used were of U.S.P. grade, and no purification other than drying with calcium chloride and a simple distillation was undertaken. A discussion of the possible significance of the curved nature of the graph of ϵ against mole fraction is given by Earp and Glasstone.[7]

The results obtained for the nitrobenzene solutions are given in Table 2.

TABLE 2

Student	*Mole fraction nitrobenzene*	*Molar polarization of nitrobenzene (cc.)*	$\mu \times 10^{18}$ E.S.U.
D	0	314	3.70
(24.5°C.)	0.0100	—	
	0.0300	281	
	0.0500	259	
E	0	349	3.89
(23.0°C.)	0.0100	333	
	0.0300	299	
	0.0500	268	
F	0	345	3.87
(22.5°C.)	0.0100	336	
	0.0300	284	
	0.0500	253	

The method of calculating μ is the same as usually employed for solution measurements at one temperature. No account has been taken of the atomic polarization term. The agreement between these values and those obtained by some investigators using research apparatus is shown in Table 3.

TABLE 3

Author	$\mu \times 10^{18}$ E.S.U.
Jenkins[12]	3.94
Chang[13]	3.82
Tiganik[14]	3.97
Williams[15]	3.90
Present (aver.)[16]	3.82

The difference between 3.82 and the other values is surprising only in so far as the difference is not larger.

[9] For corrosive materials a beaker may be mounted inside a metal container, and the container grounded to the top plate. In such cases it would be very desirable to replace C_L by a condenser made of monel metal, or stainless steel.

[10] This is approximately true as the capacity change involved here is so small that errors from inductance in the leads are less than 0.2 per cent.

[11] COOP, *Trans. Far. Soc.*, **33**, 583 (1937).

[12] JENKINS, *Nature*, **133**, 106 (1934).

[13] CHANG, *J. Chinese Chem. Soc.*, **1**, 107 (1933).

[14] TIGANIK, *Z. Physik. Chem.*, **B13**, 425 (1931).

[15] WILLIAMS, *J. Am. Chem. Soc.*, **50**, 362 (1928).

[16] It is to be noticed that student *D* has a poor measurement, having no measurement for the 0.0100 M.F. point. The average of *E* and *F* is 3.88.

The errors in the present case are surely two to three times the precision estimated by the other investigators in their work. The materials used were of U.S.P. grade, and in the case of benzene had been dried by Drierite and distilled. The density values used in the student calculations were obtained by interpolation from those given by Tiganik.[14] The temperature coefficient of density change with temperature was taken as -0.0011 gm./cc./°C. This approximation is quite good enough for student determinations, and affords a real economy in time necessary to perform the experiment. There is the additional value of acquainting the student with the use of the data from the literature, and the use of permissible approximations in applying the data to particular calculations.

SUMMARY

The apparatus described has been shown capable of moderately precise dielectric constant determinations. Its construction is simple and relatively inexpensive. The use of the equipment by students in elementary physical chemistry has proved entirely satisfactory. With proper calibration it is capable of being used as an exploratory research apparatus. The operations during a measurement are exceptionally simple and consume little time.

CHANGING CONCEPTIONS *of* MAJOR TOPICS *in* COLLEGE GENERAL CHEMISTRY TEXTBOOKS

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THE present study is essentially a continuation of a previous investigation[1] and was designed to ascertain the changing conceptions, if any, of major topics in college general chemistry textbooks from 1913 to 1937, inclusive. In the present study a tabulation has been made of twenty-five college general chemistry textbooks, so selected that the copyright date for one only occurs during each of the past twenty-five years, 1913 to 1937, inclusive. An attempt has again been made to select only books that are truly representative of the years in which each was copyrighted. By this procedure a representative sampling of college general chemistry textbooks, one for each of the past twenty-five years, has been obtained. The same general procedures and criteria were used in this tabulation as in the previous study.[1] The following twenty-five college general chemistry textbooks have been included in this study.

BLAKE, J. C., "General chemistry, theoretical and applied," The Macmillan Co., New York City, **1913.**

MELLOR, J. W., "Introduction to modern inorganic chemistry," Longmans, Green and Co., New York City, **1914.**

SMITH, ALEXANDER, "General chemistry for colleges," The Century Co., New York City, **1915.**

CADY, HAMILTON P., "General chemistry," McGraw-Hill Book Co., Inc., New York City, **1916.**

BYERS, HORACE G., "Inorganic chemistry," Charles Scribner's Sons, New York City, **1917.**

KAHLENBERG, LOUIS, "Outlines of chemistry, a textbook for college students," The Macmillan Co., New York City, **1918.**

NOYES, WILLIAM A., "College textbook of chemistry," Henry Holt and Co., New York City, **1919.**

MCCOY, HERBERT N., AND ETHEL M. TERRY, "Introduction to general chemistry," McGraw-Hill Book Co., Inc., New York City, **1920.**

NORRIS, JAMES F., "A textbook of inorganic chemistry for colleges," McGraw-Hill Book Co., Inc., New York City, **1921.**

LOWRY, T. MARTIN, "Inorganic chemistry," The Macmillan Co., Limited, London, **1922.**

NEWTH, G. S., "A textbook of inorganic chemistry," Longmans, Green and Co., New York City, **1923.**

GARARD, IRA D., "Applied chemistry," The Macmillan Co., New York City, **1924.**

NEWELL, LYMAN C., "College chemistry," D. C. Heath and Co., New York City, **1925.**

SNEED, M. CANNON, "General inorganic chemistry," Ginn and Co., New York City, **1926.**

RICHARDSON, LEON B., "General chemistry," Henry Holt and Co., New York City, **1927.**

BLANCHARD, WILLIAM MARTIN, "An introduction to general chemistry," Doubleday, Doran & Co., Inc., Garden City, New York, **1928.**

BABOR, JOSEPH A., "General chemistry, a textbook for college students," Thomas Y. Crowell Co., New York City, **1929.**

SCHLESINGER, H. I., "General chemistry," Longmans, Green and Co., New York City, **1930.**

KENDALL, JAMES, "Smith's introductory college chemistry," The Century Co., New York City, **1931.**

FOSTER, WILLIAM, "The elements of chemistry," D. Van Nostrand Co., New York City, **1932.**

NAYLOR, NELLIE M., AND AMY LE VESCONTE, "Introductory chemistry with household applications," The Century Co., New York City, **1933.**

MCPHERSON, WILLIAM, AND WILLIAM EDWARDS HENDERSON, "An elementary study of chemistry," Ginn and Co., New York City, **1934.**

[1] DUNBAR, "Changing conceptions of major topics in high-school chemistry textbooks," J. CHEM. EDUC., **17**, 394–7 (1940).

DEMING, HORACE G., "General chemistry, an elementary survey," John Wiley & Sons, Inc., New York City, **1935.**

HOLMES, HARRY N., "General chemistry," The Macmillan Co., New York City, **1936.**

HOPKINS, B. SMITH, "General chemistry for colleges," D. C. Heath and Co., New York City, **1937.**

These twenty-five college general chemistry textbooks are the product of thirteen separate and distinct publishers and are believed to be a fair sampling of the average texts of the past twenty-five years. A study of the table of contents of the several textbooks examined seemed to justify a tabulation under twenty-six major topics, instead of the twenty-four as used in the previous study.[1] The results of this study have been assembled in Table 1, which includes the number of pages and percentage of total space devoted to each of the twenty-six major topics in each of the twenty-five texts published during the past quarter century.

An examination of Table 1 indicates that these college general chemistry textbooks have been slowly but consistently increasing in size during the past quarter century. A total of eight texts, published during the past twelve years, contain more than the average number of pages (610.4) while six texts published during the first twelve years covered in this study contain less than the average number of pages for the entire period of twenty-five years. A better comparison,

TABLE 1

NUMBER OF PAGES AND PERCENTAGE OF TOTAL SPACE DEVOTED TO EACH OF THE TWENTY-SIX MAJOR TOPICS IN COLLEGE GENERAL CHEMISTRY TEXTBOOKS

Author of Textbook	*Blake*	*Mellor*	*Smith*	*Cady*	*Byers*	*Kahlenberg*	*Noyes*	*McCoy and Terry*	*Norris*	*Lowry*	*Newth*	*Garard*	*Newell*	*Sneed*
Copyright Date	*1913*	*1914*	*1915*	*1916*	*1917*	*1918*	*1919*	*1920*	*1921*	*1922*	*1923*	*1924*	*1925*	*1926*
MAJOR TOPICS														
1. Historical and Introductory Material	17	11	28	11	10	12	5	10	20	14	14	17	20	20
	4.3%	1.7%	5.5%	2.2%	1.6%	2.1%	1.5%	1.6%	3.1%	1.5%	1.9%	3.8%	3.3%	3.0%
2. Laws and Theory	41	93	77	14	107	67	11	136	101	96	76	22	124	88
	10.1%	14.5%	15.0%	2.8%	16.8%	12.1%	3.3%	21.6%	15.4%	10.6%	10.1%	4.9%	20.2%	13.4%
3. Water and Solutions	18	35	24	31	24	35	30	36	25	41	64	34	34	39
	4.5%	6.4%	4.7%	6.2%	3.8%	6.3%	8.8%	5.7%	3.8%	4.5%	8.5%	7.6%	5.6%	6.0%
4. Hydrogen	11	6	14	15	32	13	9	7	14	7	10	2	12	12
	2.8%	0.9%	2.7%	3.0%	5.1%	2.3%	2.7%	1.1%	2.1%	0.8%	1.3%	0.5%	2.0%	1.8%
5. Oxygen	15	7	15	20	24	15	13	21	22	22	46	11	23	19
	3.8%	1.1%	2.9%	4.0%	3.8%	2.7%	3.9%	3.3%	3.3%	2.4%	6.1%	2.5%	3.8%	2.9%
6. Air, Nitrogen, and Nitrogen Compounds	21	75	24	27	39	39	24	63	61	67	56	16	32	43
	5.3%	11.7%	4.7%	5.4%	6.2%	7.0%	7.1%	10.0%	9.3%	7.4%	7.4%	3.6%	5.3%	6.6%
7. Halogens	21	56	49	53	32	35	20	23	66	47	52	1	33	49
	5.3%	8.8%	9.6%	10.5%	5.1%	6.3%	5.9%	3.7%	10.0%	5.2%	6.9%	0.2%	5.4%	7.5%
8. Sulfur and Its Compounds	41	32	21	25	36	36	21	18	43	46	53	2	25	34
	10.1%	5.0%	4.1%	5.0%	5.7%	6.4%	6.2%	2.9%	6.6%	5.1%	7.0%	0.5%	4.1%	5.2%
9. The Phosphorus Group	14	18	25	28	23	34	15	16	25	40	55	1	12	27
	3.5%	2.8%	4.9%	5.6%	3.6%	6.1%	4.4%	2.5%	3.8%	4.4%	7.3%	0.2%	2.0%	4.1%
10. Boron and Silicon	21	22	8	8	13	14	6	11	14	39	18	15	10	14
	5.3%	3.4%	1.6%	1.6%	2.1%	2.5%	1.8%	1.8%	2.1%	4.3%	2.4%	3.3%	1.6%	2.1%
11. Carbon and Its Compounds	44	91	27	30	49	69	52	59	45	69	36	261	79	51
	10.9%	14.2%	5.3%	6.0%	7.8%	12.4%	15.4%	9.4%	6.9%	7.6%	4.8%	58.6%	13.0%	7.8%
12. The Alkali Metals	9	18	21	41	23	32	18	13	16	49	44	2	17	23
	2.2%	2.8%	4.1%	8.2%	3.6%	5.7%	5.3%	2.1%	2.4%	5.4%	5.8%	0.5%	2.8%	3.5%
13. The Alkali-Earth Metals	10	16	20	19	18	17	10	6	15	48	20	2	13	16
	2.5%	2.5%	3.9%	3.8%	2.8%	3.0%	3.0%	1.0%	2.3%	5.3%	2.9%	0.5%	2.1%	2.4%
14. Aluminum	7	10	9	11	19	11	4	5	12	16	10	3	11	9
	1.7%	1.5%	1.8%	2.2%	3.0%	2.0%	1.2%	0.8%	1.8%	1.8%	1.3%	0.7%	1.8%	1.4%
15. Iron and Steel	25	25	9	20	20	15	8	18	16	32	12	6	22	16
	6.2%	3.9%	1.8%	4.0%	4.6%	2.7%	2.4%	2.9%	2.4%	3.6%	1.6%	1.3%	3.6%	2.4%
16. Copper	7	6	9	17	8	9	3	7	5	21	10	1	12	12
	1.7%	0.9%	1.8%	3.4%	1.3%	1.6%	0.9%	1.1%	0.8%	2.3%	1.3%	0.2%	2.0%	1.8%
17. Silver and Gold	3	14	10	14	13	13	5	4	10	20	11	5	10	10
	0.7%	2.2%	2.0%	2.8%	2.1%	2.3%	1.5%	0.6%	1.5%	2.2%	1.5%	1.1%	1.6%	1.5%
18. Chromium and Manganese	8	19	16	17	20	15	7	4	18	22	14	1	10	13
	2.0%	3.0%	3.1%	3.4%	3.2%	2.7%	2.1%	0.6%	2.7%	2.4%	1.9%	0.2%	1.6%	2.0%
19. Tin and Lead	9	13	11	16	17	14	11	5	10	18	18	2	13	10
	2.2%	2.0%	2.1%	3.2%	2.7%	2.5%	3.3%	0.8%	1.5%	2.0%	2.4%	0.5%	2.1%	1.5%
20. Other Metals	32	21	33	52	42	40	17	11	53	102	34	19	21	53
	8.0%	3.2%	6.4%	10.3%	6.7%	7.2%	5.0%	1.8%	8.1%	11.3%	4.5%	4.3%	3.5%	8.1%
21. Colloids	1	4	—	—	—	1	2	21	—	1	—	12	2	9
	0.3%	0.6%	—	—	—	0.2%	0.6%	3.3%	—	0.1%	—	2.7%	0.3%	1.4%
22. Ionization	6	20	42	17	23	12	8	68	32	17	24	5	27	39
	1.5%	3.1%	8.2%	3.4%	3.6%	2.1%	2.4%	10.8%	4.9%	1.9%	3.2%	1.1%	4.4%	6.0%
23. Radioactivity	1	—	4	9	8	3	7	19	11	15	26	3	10	7
	0.3%	—	0.8%	1.8%	1.3%	0.5%	2.1%	3.0%	1.7%	1.7%	3.5%	0.7%	1.6%	1.1%
24. Gases and Their Measurement	4	12	5	—	3	—	14	5	11	23	19	2	18	11
	1.0%	1.8%	1.0%	—	0.5%	—	4.2%	0.8%	1.7%	2.5%	2.5%	0.5%	3.0%	1.7%
25. The Periodic Law	15	13	10	6	13	7	15	39	6	21	14	—	12	13
	3.8%	2.0%	2.0%	1.2%	2.1%	1.3%	4.4%	6.2%	0.9%	2.3%	1.9%	—	2.0%	2.0%
26. Atomic and Molecular Structure	—	—	—	—	6	—	2	4	6	13	15	—	8	18
	—	—	—	—	0.9%	—	0.6%	0.6%	0.9%	1.4%	2.0%	—	1.3%	2.8%
TOTAL	401	637	511	501	631	558	337	629	657	906	751	445	610	655
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

TABLE 1 (*Continued*)

NUMBER OF PAGES AND PERCENTAGE OF TOTAL SPACE DEVOTED TO EACH OF THE TWENTY-SIX MAJOR TOPICS IN COLLEGE GENERAL CHEMISTRY TEXTBOOKS

Author of Textbook	*Richardson*	*Blanchard*	*Babor*	*Schlesinger*	*Kendall*	*Foster*	*Naylor and Le Vesconte*	*McPherson and Henderson*	*Deming*	*Holmes*	*Hopkins*	*Average*	*Total*	*% of Total*
Copyright Date	*1927*	*1928*	*1929*	*1930*	*1931*	*1932*	*1933*	*1934*	*1935*	*1936*	*1937*			
MAJOR TOPICS														
1. Historical and Introductory Material	27	17	8	17	21	22	17	27	19	12	12	16.3	408	2.7%
	3.4%	3.0%	1.4%	2.2%	4.0%	3.6%	5.0%	3.8%	2.5%	1.8%	1.6%			
2. Laws and Theory	111	43	55	109	98	61	77	72	143	73	43	77.5	1938	12.7%
	14.2%	7.6%	9.9%	14.0%	18.4%	10.0%	22.7%	10.2%	19.1%	10.9%	5.9%			
3. Water and Solutions	48	27	55	42	32	25	21	40	28	33	36	34.3	857	5.6%
	6.1%	4.8%	9.9%	5.4%	6.0%	4.1%	6.2%	5.7%	3.7%	4.9%	4.9%			
4. Hydrogen	16	10	13	15	12	15	9	16	20	17	20	13.1	327	2.2%
	2.0%	1.7%	2.3%	1.9%	2.3%	2.4%	2.6%	2.3%	2.7%	2.5%	2.7%			
5. Oxygen	22	16	15	24	12	41	7	18	23	20	22	19.7	493	3.3%
	2.8%	2.8%	2.7%	3.1%	2.3%	6.7%	2.1%	2.5%	3.1%	3.0%	3.0%			
6. Air, Nitrogen, and Nitrogen Compounds	54	33	35	45	27	38	16	47	43	51	48	41.0	1024	6.7%
	6.9%	5.8%	6.3%	5.8%	5.1%	6.2%	4.7%	6.7%	5.7%	7.6%	6.5%			
7. Halogens	43	40	42	42	35	33	10	35	39	39	66	38.4	961	6.3%
	5.5%	7.1%	7.6%	5.4%	6.6%	5.4%	3.0%	5.0%	5.2%	5.8%	9.0%			
8. Sulfur and Its Compounds	37	38	23	43	23	25	11	30	39	29	29	30.4	760	4.9%
	4.7%	6.7%	4.2%	5.5%	4.3%	4.1%	3.2%	4.1%	5.2%	4.2%	3.9%			
9. The Phosphorus Group	16	28	23	26	9	18	12	20	14	22	34	22.2	555	3.7%
	2.0%	5.0%	4.2%	3.3%	1.7%	2.9%	3.5%	2.8%	1.9%	3.3%	4.6%			
10. Boron and Silicon	14	16	10	10	13	15	8	24	18	13	20	15.0	374	2.5%
	1.8%	2.7%	1.8%	1.3%	2.4%	2.5%	2.4%	3.4%	2.4%	1.9%	2.7%			
11. Carbon and Its Compounds	84	43	55	86	79	94	44	95	64	88	74	70.7	1768	11.3%
	10.7%	7.6%	9.9%	11.1%	14.9%	15.3%	12.9%	13.4%	8.5%	13.1%	10.1%			
12. The Alkali Metals	27	19	13	17	10	17	10	38	7	25	35	21.8	544	3.6%
	3.4%	3.4%	2.4%	2.2%	1.9%	2.8%	2.9%	5.4%	0.9%	3.7%	4.8%			
13. The Alkali-Earth Metals	18	17	10	13	11	13	2	27	19	13	26	16.0	399	2.6%
	2.3%	3.0%	1.8%	1.7%	2.1%	2.1%	0.6%	3.8%	2.5%	1.9%	3.6%			
14. Aluminum	18	14	8	11	8	9	1	17	15	20	15	10.9	273	1.8%
	2.3%	2.5%	1.4%	1.4%	1.5%	1.5%	0.3%	2.4%	2.0%	3.0%	2.0%			
15. Iron and Steel	21	21	12	16	13	18	2	26	29	18	22	18.0	451	3.0%
	2.7%	3.7%	2.2%	2.1%	2.4%	2.9%	0.6%	3.7%	3.9%	2.7%	3.0%			
16. Copper	13	10	12	21	6	7	1	8	9	9	12	9.4	235	1.5%
	1.7%	1.8%	2.2%	2.7%	1.1%	1.1%	0.3%	1.1%	1.2%	1.3%	1.6%			
17. Silver and Gold	15	19	9	6	5	9	1	10	5	6	17	9.8	244	1.6%
	1.9%	3.4%	1.6%	0.8%	0.9%	1.5%	0.3%	1.4%	0.7%	0.9%	2.3%			
18. Chromium and Manganese	13	18	13	19	12	8	1	11	2	11	17	12.4	309	2.0%
	1.7%	3.2%	2.3%	2.4%	2.3%	1.3%	0.3%	1.6%	0.3%	1.6%	2.3%			
19. Tin and Lead	14	19	12	12	16	9	1	14	6	13	18	12.0	301	2.0%
	1.8%	3.4%	2.2%	1.5%	3.0%	1.5%	0.3%	2.0%	0.8%	1.9%	2.4%			
20. Other Metals	56	48	34	31	9	43	18	45	44	46	73	39.1	977	6.4%
	7.1%	8.5%	6.1%	4.0%	1.7%	7.1%	5.3%	6.3%	5.9%	6.8%	9.9%			
21. Colloids	12	15	1	18	—	10	21	13	14	20	9	7.4	186	1.2%
	1.5%	2.7%	0.2%	2.3%	—	1.6%	6.2%	1.8%	1.9%	3.0%	1.2%			
22. Ionization	39	22	32	70	28	33	11	17	48	30	29	28.0	699	4.6%
	5.0%	3.9%	5.8%	9.0%	5.3%	5.4%	3.2%	2.4%	6.4%	4.5%	3.9%			
23. Radioactivity	13	2	13	14	6	19	9	13	10	9	4	9.0	226	1.5%
	1.7%	0.4%	2.4%	1.8%	1.1%	1.6%	2.6%	1.8%	1.3%	1.3%	0.5%			
24. Gases and Their Measurement	17	8	15	29	10	15	9	14	9	14	15	11.3	282	1.9%
	2.2%	1.4%	2.7%	3.7%	1.9%	2.5%	2.6%	2.0%	1.2%	2.1%	2.0%			
25. The Periodic Law	19	8	10	20	10	9	13	11	18	12	13	13.1	327	2.1%
	2.4%	1.4%	1.8%	2.6%	1.9%	1.5%	3.8%	1.6%	2.4%	1.8%	1.8%			
26. Atomic and Molecular Structure	17	14	26	22	26	15	8	20	65	30	28	13.7	343	2.3%
	2.2%	2.5%	4.7%	2.8%	4.9%	2.4%	2.4%	2.8%	8.6%	4.5%	3.8%			
TOTAL	784	565	554	778	531	612	340	708	750	673	737	610.4	15,261	100.0%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			

perhaps, is the fact that the twelve textbooks published during the first twelve years of this study contain a total of 6964 pages while the twelve texts published during the last twelve years contain a total of 7678 pages. This is probably due principally to the inclusion of new items of theory, research, and industrial development without an equal willingness by the several authors to delete an equal amount of obsolete material. A study of the exact number of pages devoted to each of the twenty-six major topics, as listed in Table 1, also substantiates this same conclusion. However, a better comparison of relative emphasis, or increased or decreased emphasis, can be obtained by a comparison of the percentage figures.

The twenty-five textbooks contain a total of 15,261 pages of which 1938 or 12.7 per cent. are devoted to a consideration of the laws and theories of inorganic chemistry. This topic, therefore, receives greatest emphasis among the twenty-six listed. Second in emphasis is a study of carbon and its compounds with a total of 1768 pages or 11.3 per cent. Air, nitrogen, and nitrogen compounds follow with 1024 pages or 6.7 per cent. A number of miscellaneous metals occupy nine hundred seventy-seven pages or 6.4 per cent. of the total. Other topics which follow in order of decreasing emphasis are: the halogens, 6.3 per cent.; water and solutions, 5.6 per cent.; sulfur and its compounds, 4.9 per cent.; ionization, 4.6 per cent.; the phosphorus group, 3.7 per cent.; the alkali metals, 3.6 per cent.; oxygen, 3.3 per cent.; iron and steel,

3.0 per cent.; historical and introductory material, 2.7 per cent.; the alkali-earth metals, 2.6 per cent.; boron and silicon, 2.5 per cent.; atomic and molecular structure, 2.3 per cent.; hydrogen, 2.2 per cent.; the periodic law, 2.1 per cent.; chromium and manganese, 2.0 per cent.; tin and lead, 2.0 per cent.; gases and their measurement, 1.9 per cent.; aluminum, 1.8 per cent.; silver and gold, 1.6 per cent.; copper, 1.5 per cent.; radioactivity, 1.5 per cent.; and colloids, 1.2 per cent.

TABLE 2

A COMPARISON OF THE RELATIVE EMPHASIS ON TWENTY-FOUR MAJOR TOPICS IN HIGH-SCHOOL AND COLLEGE GENERAL CHEMISTRY TEXTBOOKS

MAJOR TOPICS	High-School Texts						College Texts					
	Minimum		Maximum		Average		Minimum		Maximum		Average	
	Pages	%	Pages	%	Pages	%	Pages	%	Pages	%	Pages	%
1. Historical and Introductory Material	4	1.4	28	5.3	13.9	2.9	5	1.4	28	5.5	16.3	2.7
2. Laws and Theory	6	1.7	151	27.6	60.1	12.8	11	2.8	143	22.7	77.5	12.7
3. Water and Solutions	6	1.4	34	7.9	23.2	4.8	18	3.7	64	9.9	34.3	5.6
4. Hydrogen	1	0.2	25	4.8	9.5	2.0	2	0.5	32	5.1	13.1	2.2
5. Oxygen	1	0.4	26	6.8	14.5	3.0	7	1.1	41	6.7	19.7	3.3
6. Air, Nitrogen, and Nitrogen Compounds	5	1.9	49	12.7	30.5	6.4	16	3.6	75	11.7	41.0	6.7
7. Halogens	1	0.2	48	9.3	20.1	4.2	1	0.2	66	10.5	38.4	6.3
8. Sulfur and Its Compounds	1	0.4	37	6.2	19.3	4.0	2	0.5	53	10.1	30.4	4.9
9. The Phosphorus Group	—	—	25	3.8	9.4	2.0	1	0.2	55	7.3	22.2	3.7
10. Boron and Silicon	—	—	20	5.9	11.0	2.3	6	1.3	39	5.2	15.0	2.5
11. Carbon and Its Compounds	42	10.8	297	62.5	56.4	23.6	27	4.8	261	58.6	70.7	11.3
12. The Alkali Metals	4	1.0	33	5.5	16.1	3.4	2	0.5	44	8.2	21.8	3.6
13. The Alkali-Earth Metals	3	1.1	31	6.1	12.8	2.8	2	0.5	48	5.3	16.0	2.6
14. Aluminum	1	0.4	18	3.1	8.3	1.7	1	0.3	20	3.0	10.9	1.8
15. Iron and Steel	3	0.9	32	6.9	19.0	4.0	2	0.6	32	6.2	18.0	3.0
16. Copper	1	0.1	13	2.6	6.0	1.2	1	0.2	21	3.4	9.4	1.5
17. Silver and Gold	—	—	25	5.1	8.7	1.9	1	0.3	20	3.4	9.8	1.6
18. Other Metals*	4	1.1	116	14.8	31.2	6.5	20	3.2	142	16.9	63.5	10.4
19. Colloids	—	—	27	6.2	6.4	1.3	—	—	21	6.2	7.4	1.2
20. Ionization	—	—	46	7.9	14.8	3.1	5	1.1	70	9.0	28.0	4.6
21. Radioactivity	—	—	20	3.3	6.4	1.3	—	—	26	3.5	9.0	1.5
22. Gases and Their Measurement	—	—	19	3.6	6.7	1.4	—	—	29	4.2	11.3	1.9
23. The Periodic Law	—	—	14	2.9	7.0	1.5	—	—	39	6.2	13.1	2.1
24. Atomic and Molecular Structure	—	—	40	6.4	9.3	1.9	—	—	65	8.6	13.7	2.3

* This item represents all other metals, including chromium and manganese, and tin and lead, which were not separately tabulated in the case of the high-school texts.

A more detailed study of the percentage tendencies from year to year reveals a marked increase in the emphasis in recent years on the subjects of colloids, ionization, radioactivity, and atomic and molecular structure. And there is also a very noticeable time lag between the announcement of these related scientific discoveries and their inclusion in college general chemistry textbooks. There is some decrease in the emphasis placed upon a detailed study of the chemistry of the less common metals. The basic laws and theories, historical material, mathematical treatment of the gas laws, and a study of carbon and its compounds continue to hold an important place in recent textbooks.

A comparison with findings in the previous study[1] is worthy of some note. These comparisons can best be made in tabulated form and are summarized in Table 2.

CONCLUSIONS

In addition to the facts immediately obvious from a study of Tables 1 and 2, the following conclusions seem to be justified.

(1) Recent college general chemistry textbooks are placing an increased emphasis upon the subjects of colloids, ionization, atomic and molecular structure, and radioactivity.

(2) Greatest emphasis is placed upon the laws and theories of inorganic chemistry, with a study of carbon and its compounds occupying a close second.

(3) Recent texts are placing less emphasis upon a detailed consideration of the complex chemistry and metallurgy of numerous metallic elements.

(4) There is a slight increase in the amount of historical material contained in recent texts.

(5) Other basic topics as listed show little change in emphasis.

(6) Recent college general chemistry textbooks are increasing slightly in size, due to inclusion of new material, without an equal deletion of older material.

(7) The high-school chemistry texts place considerably more emphasis upon a study of carbon and its compounds than the college general chemistry textbooks.

(8) The college texts place slightly more emphasis than the high-school texts upon recent developments such as ionization, radioactivity, the periodic law, and atomic and molecular structure.

(9) The college texts place greater emphasis than the high-school texts upon a consideration of the chemistry of the less important metals.

(10) In all other respects, there is almost perfect agreement or duplication of emphasis on chemical subjects, as outlined in this study, by high-school and college general chemistry textbooks.

PICTURES *of* ACID-BASE REACTIONS[1]

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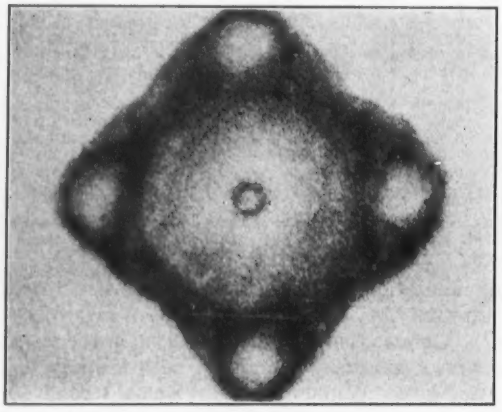
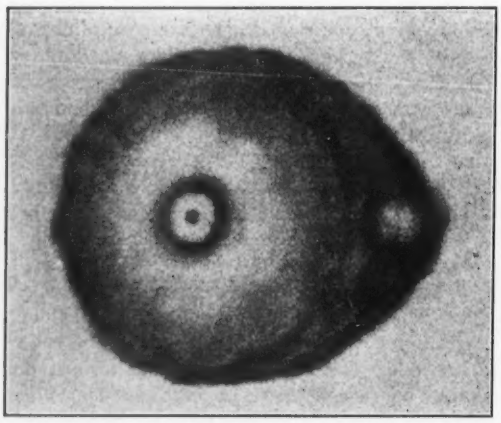
ONE of the obstacles to be surmounted in teaching the Brønsted theory of acids and bases is the very one which caused the scientists themselves to hesitate to accept it. As far as Arrhenius knew, ions of different species had individual characteristics, but the



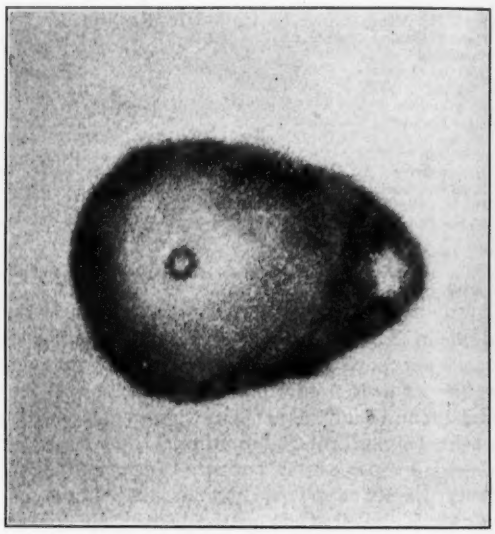
THE AMMONIUM ION

limits of variation from the average for all ions were not very wide after all. Such things as ionic radii or



THE HYDROCHLORIC ACID MOLECULE

potentials were all of the same order of magnitude. It was early recognized that all ions are solvated and that the extent of solvation varies from ion to ion. Hence the insistence of Brønsted upon the fact that hydrogen ions are *always* solvated seemed superfluous



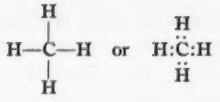
THE HYDROXYL ION

and of no particular significance since all other ions are solvated also.

The basic difference between the hydrogen ion and other ions is primarily its size. Whereas all other ions have diameters of the order of 1 Å. (apart from any shell of solvation), the diameter of the hydrogen ion is estimated to be 10^{-8} Å. This is smaller than even the nuclei of other atoms and leads to a tremendously high value of "ionic potential" (= charge/radius) compared to that of Li^+. Hence the hydrogen ion, which is just a bare nucleus entirely devoid of electron shells, actually buries itself in the electron shell of the atom to which it happens to be attached.

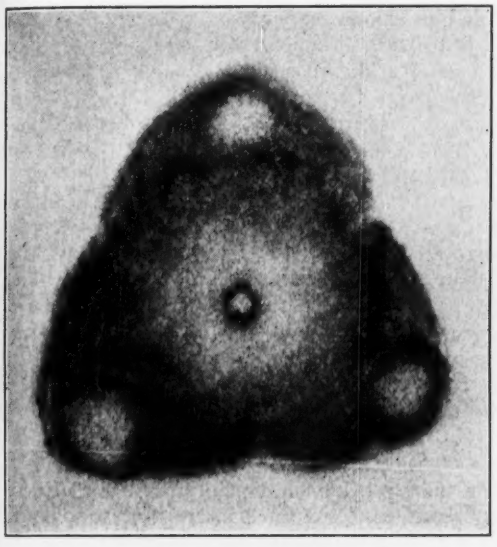
Some years ago it was pointed out (*1*) that most molecular models are inadequate in their representation of combined hydrogen because they used balls or blocks of the same size for both hydrogen and carbon, for instance. The same fault can be found with the blackboard formulas

[1] Presented before the Division of Chemical Education at the ninety-seventh meeting of the A. C. S., Baltimore, Md., April 4, 1939.



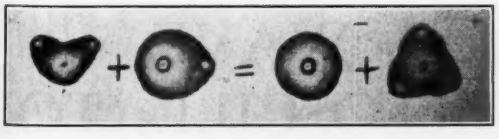
Here, too, the implication of comparable sizes of C and H persists.

To avoid this particular defect (at the risk of introducing others) a method of representing molecular structure has been tried out with considerable success in class work. This representation is based upon the



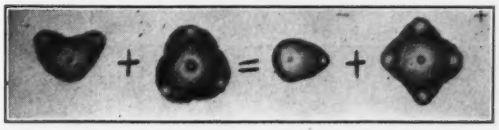
THE HYDRONIUM ION

wave-mechanics picture of the atom as a nucleus surrounded by an "atmosphere" of negative electricity the density of which is governed by the value of ψ^2, the square of the "amplitude" in the wave equation of Schrödinger. Methods of representing this atmosphere in single atoms have been worked out (*2, 3*). In



$H_2O + HCl = Cl^- + OH_3^+$

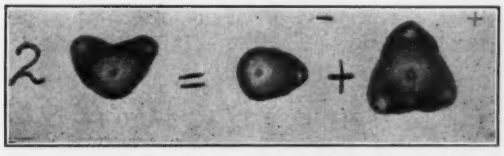
the present scheme involving polyatomic species only a qualitative representation is possible, but two features of the actual species are faithfully preserved: (1) the internuclear distances, which are pretty well known for these simple species, and (2) the arrangement of the "atmosphere" in layers or shells. On the other hand, since the representations are two-dimensional "cross-sections," no structure with non-coplanar atoms can be conveniently represented without distortion. The best that can be done is to preserve the essential elements of symmetry, a pyramidal ammonia molecule or the hydronium ion becoming triangular, and a tetra-



$H_2O + NH_3 = OH^- + NH_4^+$

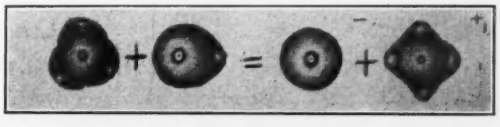
hedral ammonium ion or methane molecule becoming square.

To prepare the pictures, the positions of the nuclei are first marked. The scale used in these diagrams was 1 Å. = 2.5 inches (a magnification of roughly one to



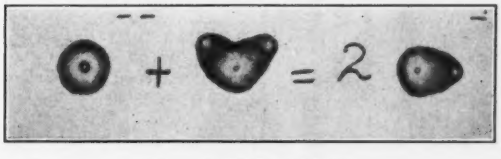
$2H_2O = OH^- + OH_3^+$

half a billion). For the sake of convenience and in the absence of definite evidence to the contrary it is assumed that the formation of covalent bonds of the



$NH_3 + HCl = Cl^- + NH_4^+$

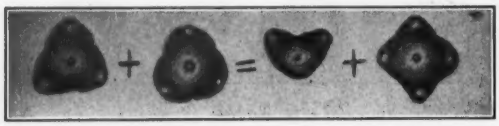
type actually present in these species has no significant effect upon any but the valence shell, so that the others are simple circles. The "radii" of these circles are taken as the maxima in the electron atmosphere and



$O^{--} + H_2O = 2OH^-$

are determined by use of the screening constants of Pauling and Sherman (*4*). Actually there are several

maxima in one shell, but they are closely spaced, and nothing is to be gained by introducing such a complication. With artist's pastel chalk in one of the more intense shades such as dark green, dark blue, dark red, or brown it is fairly easy to show the varying density of the electron atmosphere by a varying intensity of



$OH_3^+ + NH_3 = H_2O + NH_4^+$

color. The nuclei are obvious in the diagram simply as approximate centers of symmetry for the electron atmosphere in their immediate vicinity. If they are represented explicitly by a spot of color it must be clearly explained that they would actually be entirely invisible on the scale employed. The actual shape of the distorted valence shell being unknown except in the case of the hydrogen molecule (*5*), it has been arbitrarily represented.

The internuclear distances used are: O—H = 1.0, Cl—H = 1.3, N—H = 1.0, Cl—Cl = 2.0, O═O = 1.2, all in Ångstrom units. In the picture of the water molecule the angle HOH is taken as 110°. The other bond angles are obvious from symmetry.

The object of these diagrams is to drive home to the student that the proton in *any* hydrogenous species is buried in the valence shell of another atom. Thus hydrogen chloride is more properly considered as chloride ion distorted by the presence of a proton than as a combination of chlorine and hydrogen. These diagrams also show that the ammonia molecule and the hydronium ion differ only negligibly in size and shape, the single significant difference being the charge on the hydronium ion and the lack of charge on the ammonia molecule.

The presence of electron shells in the cores of *both* atoms bound by covalence causes a pronounced difference in the shape of the diatomic molecule as is shown by hydrogen chloride and chlorine. In the latter there is a decided "neck" between the atoms; in the former almost none. The representation of the double bond in oxygen is probably fanciful and unreliable, but may still be used with as much propriety as the usual blackboard formulation, O═O, which implies two parallel bonds.

Such pictures are by no means restricted to acid-base reactions. The organic chemist frequently uses models to elucidate the properties of the molecules which he is investigating. The sets of balls and sticks commonly used have only one size of ball for all atoms, a state of affairs which is tolerable for all the relevant atoms *except* hydrogen, and much confusion has resulted in the past because of the implicit assumption that a hydride is essentially the same as any other binary compound. A "picture" of methane exhibited to the class in organic chemistry would help overcome any such difficulty.

SUMMARY

The unique behavior of the proton is clarified by using charts of "electron density" to represent molecules and ions containing hydrogen. Representative charts are shown.

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An IMPROVEMENT *in the* WAVE FORM *of the* AUDIO OSCILLATOR

CREIG S. HOYT

Grove City College, Grove City, Pennsylvania

IN THE determination of electrolytic conductance, an alternating current is employed in order to prevent the deposition of gas films upon the electrodes and the production of acid and base about them. The alterations in the resistance of the electrolytic circuit as a consequence of electrode reactions due to real variations in the conductance and to the back potentials set up at the electrodes are called polarization effects. The polarization is reduced to a minimum by applying a coat of platinum black to the electrodes and

by employing a current of high frequency. It is also desirable that the current source should be such as to give a pure sine wave form free from harmonics and with no unidirectional component.

One of the more satisfactory sources of alternating current for conductance measurements is the audio

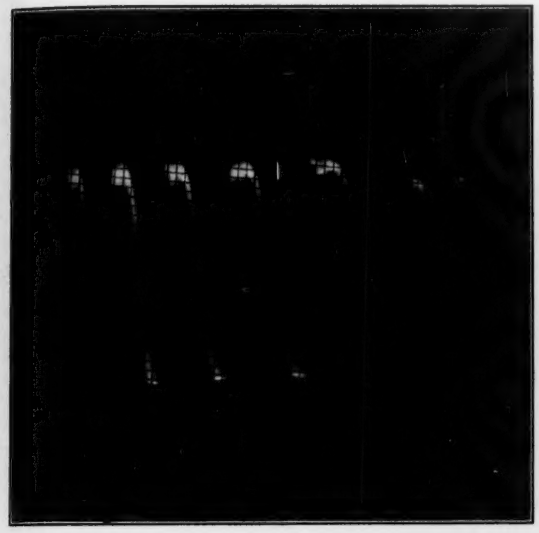

FIGURE 1

oscillator, sometimes called the microphone hummer. The frequency is held constant by using as the vibrator an electrically actuated tuning fork. It has been recognized that the wave form of this instrument is not pure as shown in Figure 1. This interferes with the determination of the balance point on the Wheatstone bridge by the use of a tuned phone as the detector.

The impure wave form of the audio oscillator appears to be due to whip in the fork; a vibration of a part of the fork with a period different from that of the fork as a whole. The wave form of the oscillator output can be greatly improved, the harmonics eliminated and any unidirectional component removed by a simple process of mechanical damping of the vibrator, insufficient to destroy the fundamental but adequate to eliminate the harmonics. Figure 2 shows the wave form of the same oscillator as in Figure 1 with a Number 5 pure gum rubber stopper resting on the fork and a weight of twenty grams applied to the top of the stopper. It is essential that the damper be resilient, and the rubber stopper is by far the most satisfactory material employed.

The effect of mechanical damping is apparent in the greater precision of location of the balance point on the

FIGURE 2

bridge. This can be measured by noting the number of divisions through which the contact point may be moved without a detectable change in the tone intensity in the phone. This simple device achieves a material improvement in the precision of the determination of electrolytic conductance.

WILLIAM WALLACE BUFFUM

William Wallace Buffum, treasurer and director of The Chemical Foundation, Inc., 654 Madison Avenue, New York City, died at the Mountainside Hospital in Montclair, New Jersey, on June 22nd, after a brief illness of a heart ailment. Mr. Buffum was born at Friendsville, Pa., on August 25, 1888. From 1917 to 1921 he was chief accountant in the Washington office of the Alien Property Custodian. Since 1921 he had been a member of The Chemical Foundation. He took an active interest in the furtherance of chemical education in this country, in the organization of the American Institute of Physics, and in the development of newsprint from Southern pine. He was also greatly interested in the utilization of chemistry in the fight against various diseases, such as cancer, tuberculosis, and others. Through his connection with The Foundation, he became business manager of several periodicals, including *The American Journal of Cancer*, *Sewage Works Journal* and *The Journal of Clinical Investigation*.

ESSENTIAL ASSUMPTIONS *of a* THEORY *of* ATOMIC STRUCTURE[1]

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Erie Center, University of Pittsburgh, Erie, Pennsylvania

(1) ATOMS are composite in nature and are made up of more elementary particles. (Note 1.)

(Note 1) Three different particles are commonly used in constructing atomic models. These are: (*a*) the negatively charged *Electron*, (*b*) the positively charged *Proton*, and (*c*) the electrically neutral particle, the *Neutron*. On the basis that a single atom of hydrogen protium weighs 1.0081 AMU (atomic mass units) the best available data indicate that a proton weighs 1.0076 AMU, a neutron weighs 1.0090 AMU, and an electron weighs 0.00054 AMU.

(2) Atoms possess a definite architecture and consist of a positively charged nucleus with a number of electrons outside the nucleus. (Note 2.)

(Note 2) It is now generally considered that all of the electrons are outside of the nucleus, *i. e.*, there are no free electrons present as individual entities inside the nucleus.

(3) The number of electrons outside the nucleus equals the nuclear charge. (Note 3.)

(Note 3) This is the same as the *Atomic Number*, *i. e.*, the number of the element as it is arranged in the Periodic Table in order of increasing atomic weight. All atoms of the same element contain the same number of electrons outside the nucleus and, conversely, all atoms of differing elements contain differing numbers of electrons outside the nucleus. Atoms which possess differing nuclei but the same number of electrons outside the nucleus are referred to as *Isotopes*.

(4) The electrons outside the nucleus are relatively distant from it and from each other. They are arranged in more or less definite shells or orbits and revolve in these orbits without loss of energy. (Note 4.)

(Note 4) These shells are commonly regarded as representing energy levels. In general, an electron in an outer shell possesses more energy than an electron in an inner shell. The number of shells which a normal atom of an element possesses is the same as the number of the Period in which the element occurs in a common form of the Periodic Table. In certain shells, sub-shells may also be found.

(5) The number of electrons in the outermost shell of a neutral atom may vary from zero to eight except in the two instances in which it is also the only shell (hydrogen and helium) and here the maximum number is two. After another shell has begun to form, additional electrons may be added to certain inner shells, but, even so, the maximum number of electrons in the next-to-the-outermost shell is eighteen, and in the next-to-the-next-to-the-outermost shell is thirty-two. The maximum number of electrons in the first four shells is, respectively, two, eight, eighteen, thirty-two. (Note 5.)

(Note 5) The arrangement of the electrons in a neutral atom is determined chiefly by their number. Of great importance is Pauli's Exclusion Principle which states, in effect, that no two electrons in any atom may possess precisely identical energies.

(6) When atoms react in the ordinary types of chemical change they do so by transferring electrons or by sharing pairs of electrons. The nucleus remains unaffected in the ordinary types of chemical change. (Note 6.)

(Note 6) The complete transfer of electrons results in the formation of electro-valent (polar) compounds; co-valent (non-polar) compounds are formed by sharing electrons. In general, electro-valent compounds are highly ionized when dissolved in water but co-valent compounds do not ionize appreciably.

(7) In the ordinary types of chemical change it is only the electrons in the outermost shell which are directly affected. These are the valence electrons. An atom tends to acquire an even number of electrons in the valence shell, especially eight (or zero). (Note 7.)

(Note 7) The entire portion of an atom inside the outermost shell is commonly referred to as the *Kernel*. The loss of all the electrons from an outer shell may result in uncovering a lower shell containing more than eight electrons, *e. g.*, Zn^{++}. Variable valence occurs commonly, but not exclusively, when an inner shell is being built up to eighteen or thirty-two electrons.

(8) The nucleus is relatively very small. However, most of the mass of an atom is in the nucleus which contains all of the protons and neutrons. (Note 8.)

(Note 8) The radius of the average nucleus is about one-ten-thousandth of that of a whole atom; the volume of the nucleus would therefore be about a million millionth of the whole atom.

(9) The number of protons inside the nucleus is equal to the number of electrons outside the nucleus. The sum of the number of protons and neutrons in an atom closely approximates the atomic weight. (Note 9.)

(Note 9) The integer which most closely approximates the

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[1] Presented before a Student Meeting of the Erie Section of the A. C. S., Erie, Pennsylvania, March 28, 1939. The material incorporated herein was distributed for the consideration of the students.

[2] Present address: Bureau of Agricultural Chemistry and Engineering, United States Department of Agriculture, Washington, D. C.

[3] Present Address: Hammermill Paper Company, Erie, Pennsylvania.

accepted atomic weight of a specific isotope is referred to as the *Mass Number* and is numerically equal to the sum of the protons and neutrons in the nucleus. The atomic number of an element is designated by a subscript placed to the left of the symbol and the mass number is designated by a superscript placed to the right. Thus $_{11}Na^{23}$ indicates an atom of sodium, atomic number 11 and mass number 23 (atomic weight 22.997).

(10) In all radioactive changes, natural and artificial, and in all cases of transmutation of elements it is fundamentally the nucleus which is affected; the outer electrons adjust themselves so that the atom as a whole remains neutral. (Note 10.)

(Note 10) Changes involving any alteration in the nucleus are generally regarded as "extraordinary changes." They are properly considered a branch of nuclear chemistry and such reactions are commonly referred to as *Nuclear Reactions*. There is reason to believe that the nucleus possesses an architecture of its own.

(11) Electrons, positrons, photons, barytrons, alpha particles, and neutrinos which are observed when emitted from the nucleus during nuclear reactions are not preëxistent within the nucleus as individual entities but are produced during the course of the nuclear reaction. (Note 11.)

(Note 11) An *Alpha Particle* is a doubly positively charged atom of helium. The *Positron* is a unit positively charged particle of mass equal to that of the electron. The *Photon* is a unit particle of light; its mass depends upon the nature of the light which it comprises and is given by Einstein's equation which relates mass and energy: $E = mc^2$ where E is the energy, m is the mass, and c is the velocity of light. A photon of a gamma ray of energy corresponding to about a million electron volts would possess the mass equivalent of a positron-electron pair. The *Barytron* is an electrically charged particle of mass several hundred times that of an ordinary electron. It is an unstable particle and possibly decomposes into an electron and energy according to the Einstein relationship. The *Neutrino* is a neutral particle of mass even less than that of the electron. The positron, barytron, and neutrino are all short-lived particles. A positron might be formed in the nucleus (and promptly ejected) from the reaction: Proton + Energy = Neutron + Positron. An electron might be formed in the nucleus (and likewise promptly ejected) by some such reaction as: Neutron + Gamma Ray = Proton + Electron + Energy.

(12) The effect of a change in the nucleus of an atom as it refers to the transmutation of elements may be explained in terms of the effect upon the nuclear charge. (Note 12.)

(Note 12) Thus if an atom loses an electron from its nucleus, *e. g.*, $_{11}Na^{23}$, its positive charge is increased by one and an atom of the next higher atomic number is produced ($_{12}Mg^{23}$); if a positron is ejected the nuclear charge is decreased by one and an atom of the next *Lower* atomic number is produced ($_{10}Ne^{23}$); if a proton is lost an isotope of neon would be obtained ($_{10}Ne^{22}$); if a proton were added an isotope of magnesium ($_{12}Mg^{24}$) would be produced, but if a neutron were added the nuclear charge would remain unchanged and an isotope of sodium ($_{11}Na^{24}$) would be produced. *Nuclear Isotopes* are also known. Thus $_{47}Ag^{106}$ may decompose to produce a positron and $_{46}Pd^{106}$, or it may decompose to produce an electron and $_{48}Cd^{106}$ and both reactions have been observed experimentally.

(13) The forces of repulsion which normally operate between like electrical charges at ordinary distances break down at nuclear dimensions and are replaced by attractive forces. (Note 13.)

(Note 13) This assumption is introduced to account for the stability of nuclei. Experimental evidence has been obtained for the existence of such attractive forces.

As a student pointed out, this is reminiscent of Pope's lines,

> "Vice is a monster of so frightful mien
> That to be hated needs but to be seen.
> But seen too oft—familiar with its face,
> We first endure, then pity, then embrace."

An IMPROVED METHOD *of* TEACHING *the* THEORY *of* GENERAL CHEMISTRY *in the* SPECIAL SECTION

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ONE of the most difficult problems that the guidance worker and the teacher face in an engineering college is that of successfully adjusting to the normal program those students who have low ability, poor backgrounds, or "blind spots" in certain subject-matter areas such as chemistry, mathematics, and physics.

In each of the courses mentioned only a limited time is available; yet a certain amount of material must be covered so that the students acquire the proper foundation for subsequent work. If these students are not placed in special sections their chances for succeeding in their work are decreased considerably.

In chemistry this difficulty of adjustment is most noticeable in the way the students go about solving assigned class problems. They normally lack suf-

ficient background and analytical ability to solve these problems. Last year an attempt was made by the authors of this article to find some way of dealing more effectively with this challenging problem. The usual teaching procedure followed in the chemistry class consisted of two lecture periods during the week and a recitation and quiz period at the end of the week. This approach was changed by substituting a discussion period for one of the lectures. Certain other modifications were also made which will be explained later in this article. The lecture was of the general type, except that emphasis was placed on the more important fundamentals. Many of the general details were left out so that more material of a fundamental nature could be covered than previously. The students were encouraged to obtain on their own the general details from the text and reference books and to drill themselves on the common factual material. In the discussion period the previous lecture was discussed in a round-table fashion by the students. Usually the instructor directed the discussion into the areas which were most fruitful in helping the students find their difficulties. The discussion itself and the blackboard problem work were carried out by the students who volunteered to answer the questions that were raised in the group. The instructor clarified any misunderstanding and added the necessary information needed to make the group learning more effective. Logical thinking was emphasized, and practical everyday information pertinent to the discussions was brought into the discussion to increase the interest of the students in the subject. In a general way the students found the discussion period to be a clearing house for their difficulties, especially those difficulties that they encountered during the lecture and their home work. The recitation period consisted of an oral or written quiz in which the instructor took the leading part. It was difficult to get two comparable sections; therefore the results obtained in the special section were compared with the results obtained in a regular section of chemistry. The same textbook was used and the same tests were given to each group. In the tables that are given below the special section is entitled Group A and the control section is designated as Group B.

The Iowa Chemistry Aptitude Placement Examination—New Series Form Y and the American Council on Education Psychological Examination were given to each entering freshman. The median score on these tests for each group is shown in Table 1. It can be readily seen that the difference in aptitude and ability is quite large in the two groups.

TABLE 1

RANKING OF THE TWO GROUPS ON THE ENTRANCE TESTS

	Number of students	*Chemistry test*	*Psychological test*
Group A	24	32 percentile	30 percentile
Group B	25	53 percentile	60 percentile

During the first quarter (the quarter plan is used at Fenn College) the regular method of teaching chemistry was used in both groups. In the second quarter Group A was made the experimental and Group B the control group. The average of the examination scores received by the students in the two groups at the end of the first and of the second quarter is shown in Table 2.

TABLE 2

RESULTS OF THE EXAMINATION GRADES OF EACH GROUP

	First quarter average	*Second quarter average*	*Chemistry entrance test*
Group A	61	71	32 percentile
Group B	79	81	53 percentile

The same examinations were given to both groups, and an attempt was made to equate the degree of difficulty of the examination given at the end of the second quarter with that given at the end of the first quarter. This attempt was not entirely successful, as can be seen from Table 2. Group B made an average at the end of the second quarter only a few points higher than the average for the first quarter. Group A made a gain of ten points, a little over three times as much as Group B. The students in Group A have had an opportunity to experience both methods of teaching. This fact made it possible to get their reaction concerning the two teaching approaches used. They were almost unanimously in favor of the special approach.

Because of the progress made and the favorable reactions of the students, the authors conclude that the approach used in the second quarter with Group A is a much more effective teaching method for the students in the special section of general chemistry.

PROGRAM OF SYMPOSIUM ON THE CHEMISTRY CURRICULUM OF THE FIRST TWO YEARS OF COLLEGE

The Symposium on The Chemistry Curriculum of The First Two Years of College will be conducted by the Division of Chemical Education at the Detroit meeting of the American Chemical Society, September 9–13, 1940.

MORNING SESSION

(1) Introductory Remarks: Nicholas D. Cheronis.

(2) "How Many Different Courses of General Chemistry Should We Try to Teach?" Speaker: H. T. Briscoe, Indiana University. Discussion: H. G. Deming, University of Nebraska.

(3) "The Function of General Chemistry in an Articulate Program of College Chemistry." Speaker: Hubert N. Alyea, Princeton University. Discussion: Stuart Brinkley, Yale University.

(4) "The Johns Hopkins Course in Freshman Chemistry." Speaker: David Harker, Johns Hopkins University.

AFTERNOON SESSION

(5) "A Combined Course in General Chemistry and Qualitative Analysis for Students Who Have Had High School Chemistry." Speaker: C. E. Ronneberg, Chicago City Colleges. Discussion: L. F. Audrieth, University of Illinois.

(6) "What Should Be the Content of Elementary Quantitative Analysis?" Speaker: W. C. Pierce, The University of Chicago.

(7) "A Summary: Trends in the Reorganization of Freshman and Sophomore Chemistry Curriculum." Speaker: J. O. Frank, Wisconsin State Teachers' College. Discussion: O. M. Smith, Oklahoma Agricultural and Mechanical College.

An IMPROVED CONDUCTIVITY APPARATUS

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SINCE the determination of the conductivity of various solutions is a commmon experiment in elementary chemistry courses, a large variety of instruments has been developed for this purpose. The one most frequently used consists of a lamp, in series with a pair of electrodes of either platinum or carbon, which plugs into a 110-volt line, such as the one formerly used in this laboratory.[1] This has the disadvantage of showing only marked differences of conductivity, although Brown and Bickford[2] have described an improved form using two lamps and a resistance by which more satisfactory comparisons can be made.

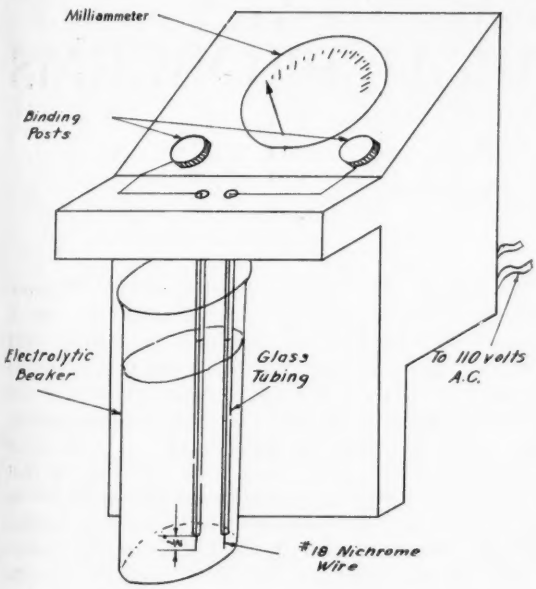

FIGURE 1.—CONDUCTIVITY APPARATUS

Another type is that sold by several apparatus houses, which makes use of some sort of current-measuring device in order to obtain semiquantitative results. As these invariably employ a six-volt battery as a source of current, they have not been entirely satisfactory, partly because of the added cost and charging nuisance, but also because of the failure to give quick, consistent readings, a fault due to the polarization effects at the electrodes.

After various attempts to work out a more satisfactory and comparatively inexpensive instrument, the one illustrated has been developed. It consists merely of an inexpensive radio milliammeter in series with a pair of electrodes, using as a source of power the output side of 6.3-volt radio power transformer, the input side of which can be connected to any ordinary 110-volt A.C. line.

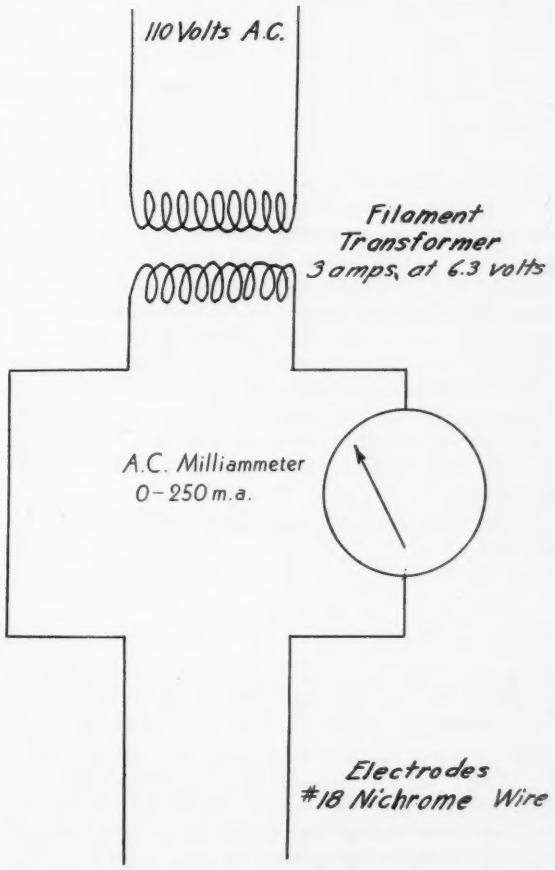

FIGURE 2.—WIRING DIAGRAM

[1] McGUIRE AND ZUFFANTI, *Sch. Sci. Math.*, **36**, 364 (1936).
[2] BROWN AND BICKFORD, J. CHEM. EDUC., **14**, 384 (1937).

With this instrument there are no polarization or other electrode effects. Thus, except in the case of certain corroding solutions, a few cents' worth of chromel wire can be used in place of the more expensive and usually less rigid platinum. Since these wires cannot be sealed in glass in the usual manner, the end of the glass tube is first closed to the desired diameter, the wire inserted and clamped in some manner while hot sealing wax is poured in to the depth of several inches, furnishing a reliable and chemically inert seal.

By using solutions of not more than half-normal strength, satisfactory comparative results can be obtained which do not require the student to estimate the different grades of brightness. If desired, the experiment described by Peterson[3] can be repeated, showing very well the increased equivalent conductivity upon dilution of a strong electrolyte such as sulfuric acid. In this case we have found the ordinary 180-ml. electrolytic beaker, pyrex No. 1025, to be a very satisfactory container for the solution.

While the cost is somewhat higher than the simple lamp-electrode set-up, there is no reason why, if the parts are purchased through a radio supply store giving the usual educational discount, it cannot be built in most school laboratories for less than three dollars for materials.

[3] PETERSON, J. CHEM. EDUC., 9, 923 (1932).

The SOLUTION *of* ELEMENTARY CHEMICAL PROBLEMS

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Georgia School of Technology, Atlanta, Georgia

In working problems, students welcome any method which requires only mechanical operations on their part. Even instructors are too often satisfied with merely the correct answer. To maintain this attitude is to defeat the very purpose of problems, which is to teach the student to reason logically and rigorously from a premise to a conclusion. The object is not so much to learn to work problems, but to learn something by working them.

Toward this end, we offer two suggestions. The first applies, no matter what method is used in solving the problems; the second is concerned with the advantages of the method of functions or variations as opposed to that of proportions.

Several illustrative problems are worked by the function method.

✦ ✦ ✦ ✦ ✦ ✦

ONE of the main difficulties faced by the students of elementary chemistry is that of working problems. And if few learn to work problems at all, fewer still learn anything by working them. To this, I believe, the majority of instructors will agree, but can anything be done about it? In this regard, we wish to offer two suggestions. The first applies no matter what method is used; the second is concerned with the relative merits of different methods.

Most students seem to think that the difference between a problem and a discussion question is that the problem involves a large amount of calculation toward the end of obtaining the correct numerical answer. This is not so. The essential difference is that the problem involves rigorous and exact reasoning from a premise to a conclusion. One must be explicit and definite. The main purpose in assigning problems is to attempt to teach the student to reason rigorously and to make exact statements. The answer is only secondary; it merely serves as a stopping point, or goal, of the reasoning. Toward this end, then, we suggest that the student be required, in working problems, to justify each step in writing by reference to a law or definition, or by mathematical reasoning. To do this, the student need only ask himself, "Why?" at each stop in the problem and then answer his query on the paper. If a student can work a given problem in this way, the instructor is justified in believing him able to solve any other problem of this type, but if the student works the problem by jotting down some figures and obtaining the correct answer, even if he works a number of these, the instructor can never be quite sure the student really knows what he is doing. We expect almost unanimous agreement with this first suggestion but almost as great a disagreement with the second—at first.

The second suggestion is essentially this. Instead of teaching proportions, teach the concept of functions or variations. If the student discovers the proportion for himself, if he can justify it and wishes to use it, allow him, but do not teach him proportions.

We feel that proportions should be discarded for the following reasons.

(1) Students learn to use proportions mechanically without feeling or assurance and therefore often make mistakes.

(2) In working a problem mechanically, the most the student can get is the correct answer; he does not enrich his mind or enhance his ability to think.

(3) In using proportions, students are using a formula which most of them cannot derive.

(4) The idea of proportion is not a pregnant one; it is static and lifeless. As a student uses proportions more and more he learns no more about them, because the difficulty is not in their complexity.

(5) Proportions do not come naturally to students. As an example, a class of fifty-three excellent students of freshman chemistry, who were steeped in the proportion idea, was given the problem, "If five gallons of gas cost $1.05, how much would seven gallons cost?" Only thirteen used proportions!

The function or variation concept has the following recommendations.

(1) The reasoning required in using this method is included in the reasoning necessary to justify the proportion. Our mistake here has been in allowing students to use proportions without justifying them, *i. e.*, substituting in the proportion formula without being able to derive this formula.

If we are dealing with two quantities, a and b, the ratio of a to b is $\frac{a}{b}$. If this ratio remains constant, *i. e.*, if

$$\frac{a}{b} = k \text{ and } \frac{a'}{b'} = k \qquad (1)$$

the quantities a and b are said to be proportional, and by the elimination of k, we write,

$$\frac{a}{b} = \frac{a'}{b'} \qquad (2)$$

This is the proportion formula.

Returning now to equation (1), we have,

$$a = kb$$

This may be written in the form

$$a \propto b \qquad (3)$$

This is read as "a is proportional to b," or "a varies as b," or "a is a linear function of b," or, even, "the ratio of a to b is constant." These steps, which are one less in number than those for proportions, are all that are necessary in using the function concept.

(2) This method replaces a blind substitution in a formula by a reasoning process. It requires the student to think or at least gives him such an opportunity. Proportions do not.

(3) In learning to work problems from this new standpoint, the student would be learning a method of wide and fruitful application in mathematics and physics, as well as in chemistry, a method which he must learn if he is to continue even a little way in science.

(4) In using this method it is almost impossible to make mistakes of the type so common with proportions (one ratio upside down) and mistakes that might occur are just as likely with proportions.

We will now apply this method to some of the most common problems in freshman chemistry.

(1) PROBLEMS BASED ON EQUATIONS

What weight of hydrogen would be obtained by the action of dilute sulfuric acid on ten grams of zinc?

It has been found by experiment that the weight of hydrogen so obtained is directly proportional to the weight of the zinc, *i. e.*,

$$\text{Weight of hydrogen} = k \times \text{weight of zinc} \qquad (4)$$

We could now solve our problem provided we knew the constant k, and we could obtain k if we knew the weight of hydrogen obtained from some given weight of zinc. This information is given by the equation for the reaction,

$$Zn + H_2SO_4 = ZnSO_4 + H_2,$$

which tells us that one gram-atomic weight of zinc (65.4 grams) yields one gram-molecular weight of hydrogen (2.0 grams). Substituting these values in (4), we get,

$$k = \frac{2}{65.4}$$

and (4) can now be written,

$$\text{Weight of } H_2 = \frac{2}{65.4} \times \text{weight of zinc}$$

$$= \frac{2}{65.4} \times 10 = 0.31 \text{ gram of } H_2$$

A wide-awake student will immediately be concerned with the units and physical significance of this constant, k. He will soon see that k is simply the weight of hydrogen obtained from one gram of zinc and, further, that this chemical problem is essentially the same as many common practical problems with which he is already familiar; for example, such a problem as, "Find the cost of eighteen eggs." I believe that most students, if confronted with this problem, would begin with,

$$\text{Cost} = \text{number of dozens} \times \text{cost per dozen} = k \times \text{number of dozens}$$

And they would say, further, that in order to give a numerical solution, it would be necessary that they know the cost of some number of eggs, in order that they might obtain the cost per dozen, *i. e.*, k, just as in the chemical problem it was necessary to know the weight of hydrogen corresponding to some weight of zinc. To see this analogy is more important than to be able to work thousands of such simple problems mechanically!

(2) GAS LAW PROBLEMS

A gas that occupies six liters at 700 mm. pressure,

occupies what volume at 500 mm. pressure, the temperature remaining constant?

Boyle found that, at constant temperature, the volume of a gas is inversely proportioned to the pressure; *i. e.*,

$$V \propto \frac{1}{P}$$

$$V = \frac{k}{P}$$

$$PV = k$$

Now we can find the value of k, knowing the value of P corresponding to a given value of V

$$700 \times 6 = k$$

Then

$$PV = 6 \times 700,$$

so long as P is in mm. of Hg and V in liters.

Now when $P = 500$ mm.,

$$V = \frac{6 \times 700}{500} = 8.4 \text{ liters}$$

In using this method, notice that one starts from the beginning and works the problem through step by step; the only formulas substituted in are those of one's own derivation.

(3) MOLAR CONCENTRATION OF SOLUTIONS

What is the molar concentration of a solution containing four grams of sodium hydroxide in 300 cc. of solution?

We are dealing here with three variables, the molar concentration, M, the volume of solution, V, and the weight of solute, w. How are these related?

At constant V, if the weight of solute be double, the molar concentration will be double, that is to say, M is directly proportional to w or

$$M \propto w$$

But for a constant, w, if V be double, M will be halved, or M is inversely proportional to V,

$$M \propto \frac{1}{V}$$

Combining these we have

$$M \propto \frac{w}{V}$$

$$M = k\frac{w}{V} \qquad \text{(I)}$$

Again, we can obtain k if we know M for a given V and w. We know these values from the definition of M, *i. e.*, M is 1 when V is 1 liter and w is 1 gram-molecular weight.

Then

$$k = 1$$

and

$$M = \frac{w}{V}$$

This expression is true for any solute so long as w is in gram-molecular weights and V is in liters.

Applying this to the above problem, we have,

$$M = \frac{4}{40} \times \frac{1000}{300} = \frac{1}{3} \text{ molar}$$

To solve this simple problem by use of proportions involves two proportions, thereby doubling the chance of error.

(4) FREEZING POINT LOWERING

Find the freezing point of a solution containing three grams of methyl alcohol in one hundred grams of water.

The variables here are the freezing point lowering, Δt, weight of non-electrolyte, w, and weight of water, W. For a given weight of water, if w be doubles, Δt is doubles, therefore,

$$\Delta t \propto w$$

But for a given w, if W be doubles, Δt is halved, therefore,

$$\Delta t \propto \frac{1}{W}$$

Then

$$\Delta t = k\frac{w}{W}$$

Now it has been found experimentally that,

$\Delta t = 1.86$ degrees when $w = 1$ gram molecular weight

and

$W = 1000$ grams

Therefore

$$k = \frac{1.86 \times 1000}{1} = 1860$$

when w is in gram molecular weights and W in grams. Then

$$\Delta t = 1860 \times \frac{w}{W} = \frac{1860 \times 3}{100 \times 32} = 1.74 \text{ degrees}$$

The freezing point will, therefore, be $-1.74°$C.

This method will be a little more difficult for the student at first, especially if he has used proportions, but its fruits will be great in the end. After all, is it not most important to furnish a student with a foundation for growth?

CONDUCTIVITY TESTS *for* REACTIONS WHICH GO *to an* END

E. L. GUNN

Robert E. Lee High School and Lee Junior College, Goose Creek, Texas

THE present article describes the design and use of a simple conductivity apparatus which has proved to be satisfactory in giving confirmation to the generally accepted reasons why double replacement reactions in solution go practically to an end through the elimination of two or more of the four varieties of ions involved. The effects of precipitation, volatility, or formation of a slightly ionized substance, such as water, upon conductivity, give excellent support to the ionic explanation usually given of irreversibility. The experiment is simple and can be performed in a short time, either by student groups or as an instructor's demonstration.

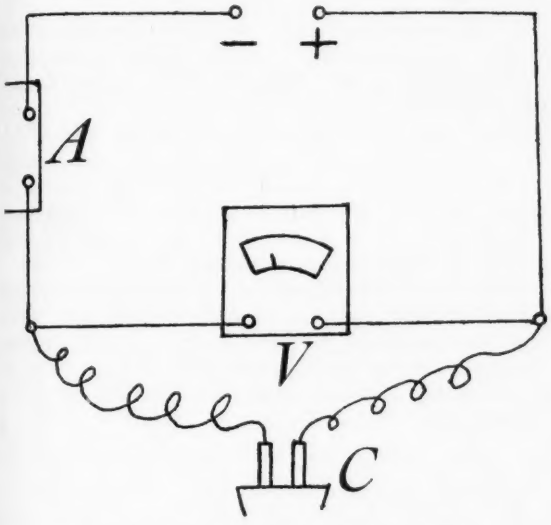


FIGURE 1.—APPARATUS FOR CONDUCTIVITY TESTS
A—ammeter
V—voltmeter
C—electrode unit

APPARATUS

Figure 1 is a schematic representation of the apparatus used in this experiment in making the conductivity tests. Direct current from an A.C.–D.C. rectifier was used. The reading of the voltmeter was constant at thirty-two volts while tests were made. The ammeter used was read in one-hundredth-ampere divisions. The electrode unit is shown in Figure 2.

PROCEDURE

Previous to the experiment, solutions of the following compounds were made in distilled water, barium hydroxide, sulfuric acid, aluminum sulfate, and sodium carbonate. Each solution was prepared by dissolving the compound until the conductivity test of the solution was 0.50 ampere.

The following double replacement reactions were caused to take place and conductivity tests were made in each case.

(1) $Al_2^{+++}(SO_4^{=})_3 + 3\,Ba^{++}(OH^-)_2 \longrightarrow 3BaSO_4\downarrow + 2Al(OH)_3$

(2) $Ba^{++}(OH^-)_2 + H_2^{+}SO_4^{=} \longrightarrow BaSO_4\downarrow + 2\,HOH$

(3) $Na_2^{+}CO_3^{=} + H_2^{+}SO_4^{=} \longrightarrow Na_2^{+}SO_4^{=} + H_2CO_3 \rightleftarrows CO_2 + H_2O$

The procedure followed in each case was as follows. Each solution was tested separately as to conductivity just before the reaction. Then, successive portions of the first reactant were added to a fixed amount of the second, with vigorous stirrings, until the minimum deflection of the ammeter was observed. Continued addition of the first reactant beyond this point brought the effective conductivity back up, of course. The electrode unit was held in the solution being tested for the length of time necessary to read the ammeter, then placed in distilled water until the next test.

RESULTS

In reaction (1) the precipitates of aluminum hydroxide and barium sulfate were clearly visible but not excessively copious. The conductivity test gave a minimum deflection which was barely sensible, therefore practically zero. This illustrates the type of reaction which goes practically to an end through precipitation. In this particular reaction both varieties of positive and of negative ions are eliminated as precipitates.

The minimum test for reaction (2) also was zero. This illustrates the elimination of two varieties of ions through the formation of a precipitate, barium hydroxide, and two varieties through the formation of a slightly ionized product—water.

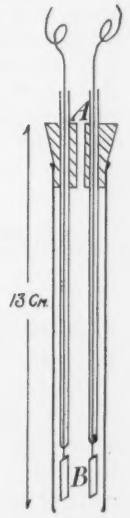


FIGURE 2.—ELECTRODE UNIT
A—air passage
B—platinum electrodes

Tests for reaction (3) differ from the two previous ones in that the minimum conductivity was not zero but 0.17 ± 0.02 ampere. The sodium and sulfate ions remain in solution to carry current. Under the conditions of the experiment, the hydrogen and carbonate ions are most probably eliminated through the results of volatility.

The reaction, $K^+NO_3^- + Na^+Cl^- \rightleftharpoons Na^+NO_3^- + K^+Cl^-$, furnishes a good example of the double replacement type in which ionic equilibrium is attained. A conductivity test applied in this case gives convincing proof that the effective current-carrying ability is not diminished by reaction. This demonstrates that there has been no change in the composition of the ions in solution to affect their ability to carry current.

CORRESPONDENCE

"BALANCING OXIDATION–REDUCTION EQUATIONS"

To the Editor

DEAR SIR:

In reply to Mr. Barthauer's communication in the February number of the JOURNAL, relative to the application of simple mathematical concepts, to the balancing of chemical equations, I beg to submit the following.

There is nothing new in the use of this idea. It has been used by two of us at the Central High School, Philadelphia, for the last ten or fifteen years at least. It is applicable, not only to oxidation and reduction changes, but to most, if not to all, other cases. Dr. Henwood and I have tried it upon some of the most difficult reactions, and it has never failed us. But we feel, in the last analysis, that the chemical method teaches more chemistry. The mathematician cannot make a start until the chemical facts are known. He is usually not trained to ascertain these facts.

We claim no originality for the method. It was explained and commented upon, in one of the earlier editions of Walker's "Physical Chemistry," some thirty odd years ago. Many of our more mathematically inclined students "lap it up" as a kitten does milk.

PHILIP MAAS

CENTRAL HIGH SCHOOL
PHILADELPHIA, PENNSYLVANIA

To the Editor

DEAR SIR:

I wish to call your attention to an article which appears in the JOURNAL OF CHEMICAL EDUCATION, **17**, 91–2 (1940), entitled, "Balancing Oxidation–Reduction Equations." The author seems to believe that this method has not been used in the past. I believe, however, that he will find it identical with one which appeared in THIS JOURNAL, **8**, 2453 (1931), entitled, "Balancing Chemical Equations."

MODDIE TAYLOR

LINCOLN UNIVERSITY
JEFFERSON CITY, MISSOURI

To the Editor

DEAR SIR:

In the February, 1940, issue there was published, under "Correspondence," a letter from Gerald Barthauer regarding the "Balancing of Oxidation–Reduction Equations."

May I state that I had a student, Walter Rothschild, in my inorganic chemistry class of 1930, who either discovered or independently rediscovered this algebraic method of balancing equations? We have used this method each year since that time, presenting it to interested students only, in our classes.

Walter Rothschild's method is the same in principle as that of Henry Green. There is one difference which can best be illustrated by a comparison. Using the method of Henry Green, from the February issue, he obtained the following algebraic equations from the reaction of,

$$a\ Cu + b\ HNO_3 \longrightarrow c\ Cu(NO_3)_2 + d\ NO + e\ H_2O$$

Cu	$a = c$
N	$b = 2c + d$
H	$b = 2e$
O	$3b = 6c + d + e$

Resolving these in terms of a, he obtains

$$a = a$$
$$b = \frac{8a}{3}$$
$$c = a$$
$$d = \frac{2a}{3}$$
$$e = \frac{4a}{3}$$

So far, Green's and Rothschild's methods are similar. However, Green lets a = unity, obtains fractional coefficients, and then clears of fractions.

Rothschild's method involves the selection of the smallest possible value of a that will permit b, c, d, and e to be *whole numbers*.

For the illustration cited, this value is, by a quick inspection, the number 3. This, when substituted, yields the coefficients

$$a = 3$$
$$b = 8$$
$$c = 3$$
$$d = 2$$
$$e = 4$$

My personal opinion is that Rothschild's method is chemically clearer and mathematically easier than Green's method. However, both these students deserve commendation for original work.

CARLETON S. SPEAR

NEW ROCHELLE HIGH SCHOOL
NEW ROCHELLE, NEW YORK

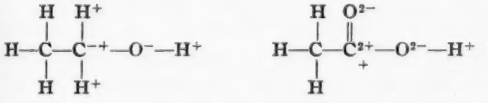
To the Editor

DEAR SIR:

Mr. Gerald Barthauer's article on "Balancing–Oxidation Reduction Equations" which appeared in THIS JOURNAL (February, 1940) brings to light a very interesting coincidence. The identical method was presented to me by a freshman student, Mr. F. Posey, while I was an assistant in freshman chemistry at the University of California at Los Angeles.

I believe that this method of balancing equations has its best application in the field of quantitative oxidation–reduction in organic chemistry. Since, at best, most methods for balancing these organic reactions are, after all, schematic, the objections that one may have to the fact that electron changes are not pictured, do not apply.

As a typical method, the one given by Robertson[1] will be contrasted with this method of "undetermined coefficients" in the oxidation of ethyl alcohol to acetic acid by means of acid dichromate.



Consider the C—C bond with valence of 0, and the CH_3 or CH_2 parts are neglected, then the net valence of the partially oxidized carbon atom in the alcohol is -1, while in the acid $3+$, a loss of four electrons. Thus four equivalents of an oxidizing agent are needed.

The method of "undetermined coefficients" would be

$$\underset{(a)}{C_2H_5OH} + \underset{(b)}{K_2Cr_2O_7} + \underset{(c)}{H_2SO_4} \longrightarrow \underset{(d)}{CH_3COOH} + \underset{(e)}{K_2SO_4} + \underset{(f)}{Cr_2(SO_4)_3} + \underset{(g)}{H_2O}$$

(C) $2a = 2d$
(H) $6a + 2c = 4d + 2g$
(O) $a + 7b + 4c = 2d + 4e + 12f + g$
(K) $2b = 2e$
(Cr) $2b = 2f$
(S) $c = e + 3f$

Now we can simplify Barthauer's method. Instead of resolving all equations in terms of a, b, or c we can let one letter equal unity at once. In this case we can let $b = 1$. Then $e = 1, f = 1, c = 1 + 3$ or 4, letting $a = d$ and solving the equation from hydrogen and oxygen.

$6d + 2c = 4d + 2g$

$d + 7b + 4c = 2d + 4e + 12f + g$

Substitute the values for b, e, f, and c

$2d + 8 = 2g$

$-d + 7 = g$ solve these two simultaneously.

$g = {}^{11}/_{2}$ and $d = {}^{3}/_{2}$, thus $a = {}^{3}/_{2}$

Multiply all by 2 and the balanced equation is:

$$3C_2H_5OH + 2K_2Cr_2O_7 + 8H_2SO_4 \longrightarrow 3CH_3COOH + 2Cr_2(SO_4)_3 + 2K_2SO_4 + 11H_2O$$

The oxidation of sodium oxalate to carbon dioxide by acid permanganate, and of secondary propyl alcohol to acetone by acid dichromate can also be easily worked out.

Although Barthauer states, "Let me say in passing that I have met with no situation in which the method is not applicable," he does admit the possibility of a limitation to the method. "No doubt, however, such problems do exist." Since this method of undetermined coefficients is in reality solving simultaneous equations with one equation less than the number of unknowns, and this equation supplied arbitrarily by letting one unknown equal unity, a discrepancy will arise if the equations prove to be inconsistant. The method also fails if we can only set up n-2 equations where n is the number of unknowns. An example is

$$(a)\ NH_4OH + (b)\ NH_3 + (c)\ Cl_2 \longrightarrow (d)\ H_2O + (e)\ NH_4Cl + (f)\ N_2$$

(N) $a + b = e + 2f$
(H) $5a + 3b = 2d + 4e$
(O) $a = d$
(Cl) $2c = e$

Here a case arises where there are four equations in six unknowns or if we let one unknown equal to unity, then we have five equations in six unknowns. Our algebraic laws say that this cannot be solved.

The limitations of this method then can be summed up as follows: Whenever a case appears where there are two more compounds than elements in a chemical reaction, the method of undetermined coefficients cannot apply.

ARTHUR FURST

PACIFIC MILITARY ACADEMY
CULVER CITY, CALIFORNIA

To the Editor

DEAR SIR:

In the February, 1940, issue of the JOURNAL OF CHEMICAL EDUCATION on pages 91–3 Gerald Barthauer writes of a new algebraic method of balancing oxidation–reduction equations. This method was fully discussed in the correspondence columns of THIS JOURNAL during the years 1931–1934. (J. CHEM. EDUC., **8,** 2453 (1931); **9,** 358–63, 560, 751–4, 944–5, 1124–6, 1299–301 (1932); **10,** 250, 707 (1933); **11,** 125 (1934).) A review of this correspondence shows that the origin of the method is in doubt, but it is found on page 218 of Fr. Rüdorff's German high-school textbook, "Grundniss der Chemie" (1919), Sir James Walker's "Introduction to Physical Chemistry" (1899), and Barker's "Textbook of Ele-

[1] ROBERTSON, "Laboratory practice of organic chemistry," The Macmillan Co., New York City, 1937.

mentary Chemistry" (1891). B. Menschutkin of Leningrad claims it was invented by V. A. Kistiakovsky in 1919. An English chemist, John H. Melville, has a copy of a Dutch text of 1897 and a German text of 1894 both of which contain the method. The German text refers to Debus (1882) who first used the method. It is therefore very old and may go back still further. Dr. H. G. Deming presented in 1934 a very worth-while criticism of the method in which he does away with all but the independent variables and so cuts down on the number of equations.

Dietz (J. CHEM. EDUC., **9**, 361 (1932)) points out that only equations where the number of linear algebraic equations is equal to one less than the number of variables can be balanced. He proposes:

$$a\ KMnO_4 + b\ H_2SO_4 + c\ H_2O_2 \rightarrow d\ KHSO_4 + e\ MnSO_4 + f\ H_2O + g\ O_2$$

as an example where only six equations can be made from eight variables.

The method is, of course, only an interesting curiosity and is far inferior for speed to the tried and tested valence-change method or for teaching value to the up-to-date ion-electron method (*Ibid.*, **4**, 1021–30, 1158–67 (1927)). I have, however, presented the algebraic method as a diversion in my second year classes. Two different students have volunteered this interesting short cut. For the equation

$$a\ Cu + b\ HNO_3 \rightarrow c\ Cu(NO_3)_2 + d\ NO + e\ H_2O$$

one of the possible final equations is

$$3e = 4c \text{ whence } e = {}^4/_3c.$$

Now all the authors in the extensive correspondence let $c = 1$ whence $a = 1$, $e = {}^4/_3$, $b = {}^8/_3$, and $d = {}^2/_3$. Then to clear of fractions multiply by three. Now the new suggestion is that we let $c = 3$. Then all the coefficients come out as whole numbers and the correct ones at that. The rule would be to give the variable on the right side of the equation the same value as that of the denominator of the fraction which is its coefficient.

$$3e = 4c, \text{ then } e = {}^4/_3c$$

The coefficient of c is ${}^4/_3$ and the denominator is 3 so let $c = 3$. Then $e = 4$, and so forth.

If $e = 4c$ it is really $e = {}^4/_1c$, so let $c = 1$.

We have come across at least one equation where even this method yields fractional coefficients at first but such exceptions are rare.

C. W. BENNETT

WESTERN STATE TEACHERS COLLEGE
MACOMB, ILLINOIS

SHORT CUTS IN BALANCING OXIDATION–REDUCTION EQUATIONS

To the Editor

DEAR SIR:

Dr. Gerald Barthauer, in the JOURNAL OF CHEMICAL EDUCATION, February, 1940, presented a method of balancing these equations. On trying this method with students in chemistry classes at West High School in Cleveland, Ohio, the following suggestions were made by students. In the equation

$$MnO_2 + NaCl + H_2SO_4 \rightarrow Cl_2 + Na_2SO_4 + MnSO_4 + H_2O$$

let coefficient of $MnO_2 = 1$, $Cl_2 = A$, $H_2SO_4 = B$, $MnSO_4 = 1$, $NaCl = 2A$, $Na_2SO_4 = A$, $H_2O = B$.

The O equation becomes $2 + 4B = 4A + 4 + B$

.. S .. .. $B = A + 1$

or $A = 1\ B = 2$ (Collecting and Solving)

The equation then is

$$MnO_2 + 2NaCl + 2H_2SO_4 \rightarrow Cl_2 + Na_2SO_4 + MnSO_4 + 2H_2O$$

We can cut down on the number of letters needed to express coefficients whenever an element occurs in only one of the compounds (or as an element) on each side of the equation. We can avoid fractions by care in the choice of coefficient that equals 1.

Thus,

Coefficient 2 6 A 6 A 1

Equation $Ca_3(PO_4)_2 + SiO_2 + C \rightarrow CaSiO_3 + CO + P_4$

The equation for oxygen becomes $16 + 12 = 18 + A$.

$A = 10$

P_4 is given a coefficient of 1 because there are more atoms here than in $Ca_3(PO_4)_2$

$$2Ca_3(PO_4)_2 + 6SiO_2 + 10C \rightarrow 6CaSiO_3 + 10CO + P_4$$

W. G. LAWRENCE

WEST HIGH SCHOOL
CLEVELAND, OHIO

A SIMPLE DETERMINATION OF THE EQUIVALENT WEIGHTS OF MERCURY, COPPER, AND ZINC—A CORRECTION

An error appears in this article which was published on page 595 of the December, 1939, issue of the JOURNAL. The proportion should read as follows:

$$x : 8 = 803 : 197$$
$$x = 32.6$$

HIGH-SCHOOL NOTES

ELBERT C. WEAVER

Bulkeley High School, Hartford, Connecticut

SCIENCE PROJECTS

R. W. WOLINE

Community High School, Gillespie, Illinois

THE use of projects and other supplementary materials is often helpful in the teaching of sciences. The author has used projects and supplementary reading reports for the past two years and has found them to be of some value. Their use has not proved to be the "cure-all" that many claim them to be. However, experience has proved that this sort of material is helpful in teaching some students.

The list of projects and reading reports which follow contain topics which have been compiled during the past two years and also lists the instructions given to the students.

No claim is made for originality, as the material was compiled from sources too numerous to mention, and while the list is far from complete it is offered with the hope that it might provide a source of ideas for supplementary materials.

OPTIONAL WRITTEN REPORTS

The topics listed on the next few pages are suggested as material which can be used to raise your grade, increase your knowledge, and to provide work for the ambitious student. These reports are to be written in ink, or typewritten, and must be approximately four hundred words in length. They should show that you have done some additional reading, or research, on the topic chosen.

Credit will be given for these reports by using the grade given on the report as a factor in determining your six-weeks grade. If you wish to secure more credit than this you may use any of these topics as a Research Topic. See the Rules for Research Topics.

Reading Reports may NOT be substituted for a Project.

Research Topics MAY be substituted for a Project.

RESEARCH

(1) Topics must be chosen from posted list. Exceptions granted only after consultation with instructor.
(2) All research *must* be completed by April 30.
(3) Reports of research will comprise the following divisions:
  (*A*) Thesis or Paper (Minimum two thousand words)
    (1) Divisions of Thesis.
      (*a*) Cover.
      (*b*) Title page.
      (*c*) Table of contents.
      (*d*) Written account of work.
      (*e*) Bibliography.
  (*B*) Drawings, Diagrams, Pictures, Displays, and so forth.
    (1) Should you desire drawings, diagrams, and pictures, they may be distributed through the thesis.
    (2) It is almost necessary in research of this kind that you prepare, whenever possible, your own diagrams, models, and materials.
(4) Papers and all research materials need not be in duplicate unless you want to keep a copy. Must be in ink or typewritten (double-space).
(5) Research work will be substituted for one-half or all of the second semester examination according to type of work done.
(6) Any student neglecting his daily work for research will be requested to drop research until daily work is satisfactory to instructor.
(7) Research is open to Chemistry and Physics students only. Some exceptions may be made in General Science.
(8) You *must* consult instructor to secure his approval before starting a research topic.
(This is not necessary for a reading report.)

READING OR RESEARCH TOPICS (CHEMISTRY)

(1) Abrasives.
(2) Alchemy.
(3) Alloys.
(4) Aluminum.
(5) Atoms.
(6) Anaesthetics.
(7) Atomic models.
(8) Asbestos.
(9) Bacteria.
(10) Bakelite.
(11) Baking (pastries, cookies, cakes, and so forth).
(12) Baking powder.
(13) Beverages—carbonated.
(14) Bleaching.

(15) Candy, Chemistry of.
(16) Candy, Coal tar dyes in.
(17) Carbon.
(18) Carborundum.
(19) Ceramics.
(20) Cement.
(21) Cellulose, rayon, artificial silk.
(22) Chewing gum.
(23) Coal.
(24) Coal tar.
(25) Coal tar products.
(26) Cocoa.
(27) Colloids.
(28) Corn products.
(29) Cosmetics.
(30) Dentifrices (tooth paste).
(31) Duco.
(32) Digestion, Enzymes aiding process of.
(33) Electrolytic refining of metals.
(34) Edible oils, Hydrogenation of.
(35) Fireworks.
(36) Fertilizers.
(37) Fire extinguishers.
(38) Flavorings and extracts.
(39) Food adulterations.
(40) Gasoline.
(41) Glass.
(42) Glue.
(43) Glycerine.
(44) Graphite.
(45) Hydroelectric plants.
(46) Illumination, Relation of chemistry to.
(47) Industrial poisons.
(48) Inks.
(49) Iron.
(50) Lacquers.
(51) Laundering.
(52) Lead.
(53) Leather.
(54) Linoleum.
(55) Lime and limestone.
(56) Liquid fuels—semi-solid.
(57) Lubrication, Some problems of.
(58) Matches.
(59) Medicine.
(60) Nitrogen.
(61) Paints.
(62) Pens.
(63) Pencils.
(64) Perfumes.
(65) Petroleum.
(66) Photoelectricity.
(67) Photography, Chemistry of.
(68) Plants, Chemistry of.
(69) Pottery.
(70) Precious stones, imitation and artificial.
(71) Patent medicines.
(72) Potash, Supply of.
(73) Radio.
(74) Road construction.
(75) Rubber.
(76) Silk.
(77) Sewage disposal.
(78) Soap. (*Cf., Sch. Sci. Math.*, **38,** 393 (Apr., 1938)).
(79) Stains.
(80) Steel.
(81) Sugar.
(82) Telephone.
(83) Television.
(84) Thermite.
(85) Textiles.
(86) Water purification.
(87) War explosives.
(88) War gases.
(89) Vitamins.
(90) Zinc.
(91) Radium, Curies, and medicine.
(92) Diabetes, and treatment.
(93) Heavy water. (*Cf., Sch. Sci. Math.*, **37,** 1034 (Dec., 1937)).

READING OR RESEARCH TOPICS (PHYSICS)

(1) Aircraft and their engines.
(2) Aircraft and their construction.
(3) Atmosphere, Pressure of.
(4) Aurora borealis, Electrical effects of.
(5) Artificial lightning.
(6) Batteries and power.
(7) Caissons and cofferdams.
(8) Change of state.
(9) Compressed air machinery.
(10) Death rays.
(11) Electricity, Heating effects of.
(12) Electrons.
(13) Electromagnetism.
(14) Electrochemistry.
(15) Energy and power.
(16) Fluid pressures, Transmission of.
(17) Friction, How it may be decreased.
(18) Heat from fuels.
(19) Heat from the stars.
(20) Heat and the structural engineer.
(21) Inaudible sounds.
(22) Lenses—microscopes.
(23) Invisible light.
(24) Illumination and its measurement.
(25) Lighter-than-air machines.
(26) Lightning Rods, Their present-day use.
(27) Light waves and color.
(28) Magnetism.
(29) Molecules and their behavior.
(30) Optical instruments.
(31) Percussion and destruction of bridges and buildings.
(32) Radium and energy.
(33) Engines, Steam.
(34) Engines, Gas.
(35) Engines, Oil.
(36) Simple machines of the ancients.
(37) Stars and their composition.
(38) Strings and air columns in music.
(39) Sun engines (Gobi desert).
(40) Telescopes—construction and operation.
(41) Thermal power.
(42) Vacuum tubes and radio communication.
(43) Water power.
(44) X-rays and life.
(45) Long range guns.
(46) Tanks—Operation and usefulness in war.
(47) Submarines—Sources of power.
(48) Automatic stokers.
(49) Smoke prevention.
(50) Harbor protection.
(51) Mine machinery and its operation.
(52) Some problems in mine ventilation.
(53) The application of power and energy in mines.
(54) Air-conditioning.
(55) The story of the standard meter.
(56) Gold beating and gold beaters' skin.
(57) Story of the Keokuk, The Roosevelt, The Muscle Shoals or some other irrigation or power dam. Particular attention is to be given to the engineering rather than the historic features.
(58) A history of the development of weights and measures
(59) The history of the Westinghouse air brakes.
(60) Sinking the piers of a bridge.

(61) Compressed air coal-mining machinery.
(62) Making liquid carbon dioxide.
(63) The Foucault Pendulum experiment.
(64) The centrifugal cream separator; its construction and manner of operation.
(65) History of aviation including the flights of Prof. S. P. Langley and of the Wright Brothers at Kitty Hawk, North Carolina.
(66) History of the steam engine.
(67) History of internal combustion engine.
(68) History of the bicycle.
(69) History of the automobile.
(70) History of turbine water wheels.
(71) Write about a trip to a liquid carbon dioxide plant or a plant where liquid air is made.
(72) The making of a thermometer. See pamphlet issued by the Taylor Instrument Company.
(73) Make a written report on a trip actually made to a plant where artificial ice is made.
(74) The nature of gases. See "Concerning the Nature of Things," by Sir William Bragg, Chapter II.
(75) Treatment of walls of auditoria with sound-absorbing materials.
(76) Right- and left-handed sugar (dextrose and levulose). A study of the use of the polariscope in the sugar and allied industries.
(77) History of electric lighting—Encyclopedia.
(78) Source of the sun's light and heat. Any up-to-date advanced astronomy text.
(79) "Rings around the Moon and Sun." See "Concerning the Nature of Things."
(80) Twilight and its causes. See "Astronomy" by Young. The following seven lessons are from "Lighting Sales Course," published by the National Electric Light Association.
(81) Illumination.
(82) Principles of illumination.
(83) Residence lighting.
(84) Store lighting.
(85) Office and public building lighting.
(86) Industrial lighting.
(87) Outdoor lighting.
(88) Magnetism, terrestrial. New International Encyclopedia.
(89) Terrestrial influence of sun-spots; magnetic storm. See "Astronomy" by Russell-Dugen-Stewart, p. 209.
(90) History of electric railway systems.
(91) History of the incandescent lamp.
(92) Description of the Edison three-wire system of electric distribution.
(93) History of the invention of the electric motor.
(94) Write a paper showing the essential differences between the direct current, the single phase, and the three-phase alternating current electric motors.
(95) Write a paper setting forth briefly the specific contributions of James Clark Maxwell, Heinrich Rudolph Hertz, Guglielmo Marconi, Lee DeForest and Major Armstrong in the development of radio transmission.
(96) Write a paper showing the specific contributions of Antoine Henri Becquerel, Madame Curie, and of E. Rutherford in the discovery and development of radioactivity.

MISCELLANEOUS

(1) Thirteen-month calendar. (*Cf., Sch. Sci. Math.*, **38**, 575, (May, 1938).)
(2) Extinct birds or those on the wane, with emphasis on conservation.
(3) Thermometry. (*Cf.*, J. CHEM. EDUC., **11**, 448 (Aug., 1934).)

FAMOUS SCIENTISTS

The following list contains names of people that have made an important contribution in some field of science. A biographical report on any of these will be worth while.

Rules for these reports are the same as for Reading or Research Topics.

BIOGRAPHIES

(1) Blaise Pascal.
(2) Robert Hooke.
(3) Archimedes. (*Cf., Iowa Science Teacher*, **4**, 51 (May, 1938).)
(4) Evangelista Toricelli.
(5) Galileo Galilei.
(6) Sir Isaac Newton. (*Cf., Iowa Science Teacher*, **4**, 77 (Sept., 1938).)
(7) Jean Bernard Leon Foucault.
(8) Prof. S. P. Langley of the Smithsonian Institute.
(9) Orville and Wilbur Wright.
(10) Thomas A. Edison.
(11) Henry Ford.
(12) James Watt.
(13) Lord Kelvin (William Thompson).
(14) James Dewar.
(15) Robert Boyle.
(16) John Tyndall.
(17) Herman Ludwig Ferdinand von Helmholtz.
(18) Christian Hygens.
(19) Henry Augustus Rowland.
(20) Augustin Jean Fresnel.
(21) Thomas Young.
(22) William Gilbert.
(23) Joseph Henry.
(24) Samuel B. F. Morse.
(25) George Simon Ohm.
(26) André Marie Ampère.
(27) Allessandre Volta.
(28) James Clark Maxwell.
(29) Heinrich Rudolph Hertz.
(30) Guglielmo Marconi.
(31) Lee DeForest.
(32) Major Armstrong.
(33) Antoine Henri Becquerel.
(34) Madame Curie.
(35) E. Rutherford.
(36) Albert Einstein.
(37) Gauss.
(38) RALPH E. DUNBAR, "Historical materials in college general chemistry textbooks," J. CHEM. EDUC., **15**, 183–6, (Apr., 1938), has a very long list of names.

SCIENCE PROJECTS

(A) *Required* of each student.
(B) Must be permanent, requiring considerable time and labor to make. (At least twenty-five hours.)
(C) Will not be returned. (With few exceptions.) These are to be considered as your permanent, and tangible, donation to the Science Department. The better ones may be placed on display.
(D) Due on the last day of April.
(E) Credits: Project will be one-half of last six weeks' grade. More credit may be given at the discretion of the instructor.
(F) If you have some worth-while project of your own, you may use it instead of one of those listed.
(G) Two or more students may work on some of the projects.
(H) Secure instructor's approval before you start on a project.
(I) If you have any questions, please see instructor.

LIST OF PROJECTS[1]

(1) "Newspaper Clippings" required of all students unless you do a project. One thousand column inches and one

[1] Instruction sheets may be secured from *The Illinois Chemistry Teacher* for marked items.

hundred articles of a scientific nature. Pictures and magazine articles will count one-half of their length.

(2) Steam engine, 1 kg. cm./sec. power, or open, cut away, model.
(3) Short wave receiver, 1 tube.
(4) Short wave transmitter, 1 watt.
(5) Radio set, 2 tube.
(6) Weather forecasting, four and one-half months.
(7) Travel book: twenty-five pages, twenty-five pictures. At least three maps desired. Specialize in three major localities.
(8) Sun dial. Permanent, accurate. Diameter over ten inches.
(9) Library reading: One thousand pages of approved science material (not over two hundred pages from periodicals, biographies, and so forth). Ten-page report with five illustrations.
(10) Sextant, usable.
(11) Telescope and magnification determination.
(12) Balloon (twenty-four inch) or Dirigible (thirty-six inch) Model (H_2 furnished).
(13) Generator or motor-(power-1 kg. cm./sec.).
(14) Pin-hole camera and pictures it has taken.
(15) Two-way telegraph outfit. Also must know code.
(16) Coal mine model with at least five samples.
(17) Bird house (showing twenty-five hours of work).
(18) Fossil collection (five) labeled and classified. Describe place where found.
(19) Insects (twenty-five) (mounted-labeled) both common and scientific name.
(20) Seeds (twenty-five) must be from one of the following groups: (*a*) Vegetables, (*b*) Grain, (*c*) Weeds.
(21) Skulls (*a*) five skulls—one from each major class of vertebrates (mounted and labeled). (*b*) Large skull mounted with all bones and fissures (labeled).
(22) Butterfly pictures: Five types of butterflies mounted behind glass. Neat. Labels on back of picture.
(23) Bird egg mounts: Mold by using clay, wax, wood, and so forth, and exact model of (ten) bird eggs; color, size, shape correct. *No* wild bird eggs accepted.
(24) Vegetable experiment garden: Takes two to three months research and data on such problems as the following:
  (*a*) Depth in planting seed.
  (*b*) Quantity of moisture.
  (*c*) Kinds of fertilization.
  (*d*) Cross-pollenization.

  Each plant must be examined, and its size and condition reported. One or more graphs included.
(25) Flower garden: Same as above, only using flowers.
(26) Qualitative analysis. Two to five salts given as unknowns. Chart showing procedure and results.
(27) Quantitative analysis. Problem given by instructor. Chart showing procedure and results. THE LESS THE ERROR THE BETTER THE GRADE.
(28) Periodic chart.
(29) Research or thesis (see list of acceptable topics).
(30) Scale drawing of laboratory.
(31) Cabinet to hold road maps.
(32) Most Boy Scout Merit Badges.
(33) Most Girl Scout Merit Badges.
(34) Chemical map.
(35) Frasch process models.
(36) Chart or collection of coal tar products.
(37) Chart showing steps in manufacture of dyes.
(38) Chart or collection of petroleum products.
(39) Chart showing steps in manufacture of photographic films.
(40) Chart showing steps in developing pictures.
(41) Model of water works plant.
(42) Model of sewage disposal plant.
(43) Model of Bessemer process.
(44) Chart of Bessemer process.
(45) Model of contact sulfuric acid process.
(46) Chart of contact sulfuric acid process.
(47) Scheme to show activity of halogens. (*Cf., Science Leaflet*, **11**, 36 (Oct. 21, 1937).)
(48) Liquefy various gases as SO_2, NH_3, and so forth. (*Cf., ibid.*, **11**, 36 (Oct. 21, 1937).)
(49) Make notebook of science radio programs.
(50) Make several atomic models. (*Cf.*, J. CHEM. EDUC., **16**, 192 (Apr., 1938) and *ibid.*, **13**, 564 (Dec., 1936).)
(51) Make a set-up to show series and parallel circuits.
(52) Leaf collection (twenty-five different leaves mounted).
(53) Construct a Wheatstone bridge. (*Cf., Ill. Sci. Teacher*, 16 (Feb., 1938).)
(54) Make a miniature geyser. (*Cf., ibid.*, 16 (Dec., 1937).)
(55) Make a collection showing how metric system is used in business world today.
(56) Weigh an auto or truck by inking tires, putting impression on paper and calculate weight of truck or auto by using the proper mathematical formulas.
(57) Make a radio set which will receive.
(58) Make an astronomy umbrella.
(59) Tesla coil. (*Cf., Sch. Sci. Math.*, **38**, 496 (May, 1938).)
(60) Model airplanes.
(61) Indicator chart (for chemistry).
(62) Telescopes.
(63) Geological time maps.
(64) Geological area maps.
(65) Leaf margin collection.
(66) Insect gall collection.
(67) Cellophane leaves.
(68) Collect bird pictures.
(69) Photographs of laboratory apparatus set-ups. (*Cf.*, J. CHEM. EDUC., **11**, 546 (1934).)
(70) Diagrams of laboratory apparatus set-ups.
(71) Fractional distillation of crude oil.
(72) Chart of a coal mine.
[1](73) Vitamin project.
[1](74) Artificial stomach.
[1](75) Observing heredity with the Drosophila fly.
[1](76) Examination of bacteria in the milk supply.
[1](77) Analyzing the water supply for bacteria.
[1](78) Mold cultured cheese.
[1](79) Cheddar cheese.
[1](80) Field study of bird.
[1](81) Mounting birds.
[1](82) Embryos of fish, birds, and mammals.
[1](83) Testing lubrication oil.
[1](84) Hydrogenation of vegetable oils.
[1](85) Getting sugar from corn.
[1](86) Rayon—synthetic.
[1](87) Photography.
[1](88) Making paint.
[1](89) Making plastic wood.
[1](90) Making Bakelite.
[1](91) Making lime.
[1](92) Making polish—wax type.
[1](93) Mirror making.
[1](94) Electroplating.
(95) Testing cloth fibres.
[1](96) Obtaining and using casein from milk.
[1](97) Making ink.
[1](98) Tanning leather.
[1](99) Crystal growing.
[1](100) Making models of mineral crystals.
[1](101) Clay modeling.
[1](102) Etching designs and photographs on metal.
[1](103) Fur tanning.
[1](104) Making baking powder.
[1](105) Dyeing cloth.
[1](106) Making vanishing cream.
[1](107) Making cold cream.
[1](108) Preservation of food.
[1](109) Make a poster containing vials of chemicals showing analysis of several brands of baking powders.
(110) Effect of different chemical fertilizers on plant growth.

(111) Make shoe polish.
(112) Make library paste or mucilage.
(113) Make putty or wallpaper cleaner.
(114) Make a museum mount of a bird or an animal.
(115) Electroplate an iron spoon.
(116) Etch glass so as to make a design.
(117) Model to demonstrate the relation between kinetic energy and velocity. (*Cf., Sch. Sci. Math.*, **38,** 518 (May, 1938).)
(118) Construct vacuum pump apparatus. (*Cf., ibid.*, **38,** 550 (May, 1938).)
(119) Magnetic force. (*Cf., ibid.*, **28,** 358 (Apr., 1928).)
(120) Density of liquids. (*Cf., ibid.*, **38,** 359 (Apr., 1939).)
(121) Conductivity of metals. (*Cf., ibid.*, **38,** 359 (Apr., 1938).)
(122) Common woods. (*Cf., ibid.*, **38,** 362 (Apr., 1938).)
(123) Conductivity of solutions. (*Cf., ibid.*, **38,** 360 (Apr., 1938).)
(124) Mercury vacuum pump. (*Cf., ibid.*, **38,** 376 (Apr., 1938).)
(125) Copper etching. (*Cf., ibid.*, **38,** 376 (April, 1938).)
(126) Water filtration plant model. (*Cf., ibid.*, **38,** 454 (Apr., 1938).)
(127) Diet experimentation (several students). (*Cf., ibid.*, **38,** 243 (March, 1938).)
(128) Make maps showing course of birds that fly long distances. Secure picture or model of the birds if possible to do so.
(129) Fix our model T engine so it can be operated by an electric motor. (Motor furnished.)
(130) Construct a large model electric bell which will work.
(131) Construct several types of cartesian divers. Write a short explanation of the operation of each. (*Cf., Sch. Sci. Math.*, **38,** 141 (Feb., 1938).)
(132) Make an alphabetical list of scientific words found in newspapers or magazines. (250 words.) Be able to use each word correctly.
(133) Make a reflector—a box with light bulbs, shiny reflectors and a lens so constructed that one can project textbook pages, photographs, postcard pictures, etc., upon a screen.
(134) Make five lantern slides.
(135) Plant seed in flower pots and care for flowers. Written report necessary.
(136) Forms of calcium carbonate (marble). (*Cf., Sch. Sci. Math.*, **37,** 910 (Dec., 1937).)
(137) Stamps and Chemistry. (*Cf., ibid.*, **37,** 910 (Nov., 1937), and J. CHEM. EDUC., **11,** 259–66 (May, 1934).)
(138) Take pictures of animals or birds, "in the field." (*Cf., Science Leaflet*, **10,** 1 (Jan. 7, 1937).)
(139) Make a Microprojector. (*Cf., Sch. Sci. Math.*, **37,** 933 (Nov., 1937) and J. CHEM. EDUC., **15,** 16 (Jan., 1938).)
(140) Make three improved overflow cans. (*Cf., Sch. Sci. Math.*, **37,** 935 (Nov., 1937).)
(141) Construct a constant temperature oven.
(142) Construct an oven—no temperature control.
(143) Construct a fireless cooker.
(144) Make a lever for physics lab. (*Cf., Sch. Sci. Math.*, **37,** 977 (Nov., 1937).)
(145) Make a large set of weights for lab. (*Cf., ibid.*, **37,** 978 (Nov., 1937).)
(146) Make a large wheel and axle for lab. (*Cf., ibid.*, **37,** 979 (Nov., 1937).)
(147) Make a H_2S generator. (*Cf.*, J. CHEM. EDUC., **14,** 581 (Dec., 1937) and *ibid.*, **13,** 588 (Dec. 1936).)
(148) Model to demonstrate effect of heat on a confined volume to gas. (*Cf., ibid.*, **15,** 394 (Aug., 1938).)
(149) Make six buret holders. (*Cf., ibid.*, **15,** 335 (July, 1938).)
(150) Make display cases. (*Cf., ibid.*, **15,** 219 (May, 1938).)
(151) Periodic system of elements. (*Cf., ibid.*, **15,** 180 (Apr., 1938).)
(152) Make a Bakelite plastic. (*Cf., ibid.*, **15,** 43 (Jan., 1938).)
(153) "Fix Nitrogen." (*Cf., ibid.*, **14,** 73 (Feb., 1937).)
(154) Color tone photographic prints. (*Cf., ibid.*, **14,** 31 (Jan., 1937).)
(155) Hydrochloric acid plant model. (*Cf., ibid.*, **13,** 564 (Dec., 1936).)
(156) Permutit water softener. (*Cf., ibid.*, **13,** 564 (Dec., 1936).)
(157) Solvay soda plant. (*Cf., ibid.*, **13,** 564 (Dec., 1936).)
(158) How much H_2 combines with 16 grams of O_2? (*Cf., ibid.*, **13,** 585 (Dec., 1936) and do the experiment.)
(159) Density demonstration apparatus. (Cf., *ibid.*, **13,** 589 (Dec., 1936).)
(160) Make 3 CO_2 generators. (*Cf., ibid.*, **13,** 539 (Nov., 1936).)
(161) Make a hot-plate. (*Cf., ibid.*, **12,** 336 (July, 1935).)
(162) Ultramicroscope. (*Cf., ibid.*, **11,** 570 (Oct., 1934).)
(163) Oxidize ammonia to nitric acid. (*Cf., ibid.*, **11,** 575 (Oct., 1934).)
(164) Make an alpha-ray track apparatus. (*Cf., ibid.*, **11,** 576 (Oct., 1934).)
(165) Make apparatus to demonstrate electrolytic conductivities. (*Cf., ibid.*, **14,** 384 (Aug., 1937).)
(166) Test water for impurities. (*Cf.*, Exp. 11, p. 63, "Workbook and Laboratory Manual in Chemistry," by Jones, Matheas, Weister, College Entrance Book Co., New York, N. Y.)
(167) Prepare a chart showing uses of chemistry in the home.
(168) Prepare a chart showing uses of physics in the home.
(169) Make a hygrometer.
(170) Make a hydrometer and calibrate it. (Loaded test-tube works nicely.)
(171) Make a gram-molecular volume box.
(172) Make collection of oxides.
(173) Make collection of sulfides.
(174) Make working model of Nelson cell for electrolysis of sodium chloride.
(175) Chart to show CO_2-O_2 cycle.
(176) Chart to show nitrogen cycle.
(177) Silver a mirror.
(178) Make CO_2 fire extinguisher.
(179) Chart showing how to remove stains.
(180) Make an activity series chart.
(181) Model of Solvay Process.
(182) Making a light bulb burn without connecting it to current. (*Cf., Science Leaflet*, **10,** 36 (Sept. 17, 1936).)
(183) Make a telescope mirror. (*Cf., ibid.*, **11,** 39 (Nov. 18, 1937).)
(184) Photographs of eight completed projects are on pages 20 and 21, *Science Leaflet*, **11** (Jan. 7, 1937).
(185) Diffraction of light. (*Cf., Science Leaflet*, **11,** 19 (Mar. 31, 1938).)
(186) Preparation and properties of an alloy.
(187) Photographs of four completed projects. (*Cf., Science Leaflet*, **10,** 34 (April 29, 1937).)
  (*a*) Water content of foods.
  (*b*) Metallic elements.
  (*c*) Open hearth process.
  (*d*) Bessemer process.
(188) Model pasteurization plant.
(189) Two photographs of projects. (*Cf., Science Leaflet*, **11,** 28 (May 5, 1938).)
(190) Poisons we eat every day.
(191) A photoelectric cell. (*Cf., ibid.*, **11,** 18 (May 5, 1938).)
(192) Atlantic City Exhibit of Student Science Clubs of America, *Science Leaflet*, **10,** 1–5 (Jan. 21, 1937), has several suggestions.
(193) Model filter bed. (*Cf., ibid.*, **10,** 35–36 (Mar. 18, 1937).)
(194) Bleaching cloth. (*Cf., ibid.*, **9,** 39 (Oct. 8, 1936).)
(195) Electroplating set-up. (*Cf., ibid.*, **11,** 34 (Mar. 3, 1938).)
(196) Cottrell process of smoke precipitation. (*Cf., ibid.*, **11,** 36 (Feb. 3, 1938).)
(197) How to make a reflecting telescope. (*Cf., ibid.*, **11,** 33 (Jan. 27, 1938).)
(198) Home-made respiration apparatus. (*Cf., ibid.*, **9,** 35 (Dec. 3, 1936).)
(199) Photographs of exhibit of posters, and so forth, on carbon and its compounds. (*Cf., ibid.*, **9,** 10 (Dec. 3, 1936).)
(200) Preparation of bromine. (*Cf., ibid.*, **10,** 31–38 (Jan. 28, 1937). photograph and description.)

(201) Making malachite. (*Cf.*, *Science Leaflet.*, **10**, 31–38 (Jan. 28, 1937).)
(202) Demonstration solvay process model. (*Cf.*, *ibid.*, **9**, 34 (Oct. 15, 1936), photograph, diagram, and description.)
(203) Chart on acetic acid and its uses provides a good sample on this type of project. (*Cf.*, *ibid.*, **9**, 14 (Oct. 15, 1936).)
(204) Map of world naming the great scientists in each country.
(205) Map of world showing one or more sources of each of the ninety-two elements.
(206) Map of the United States showing the location of the physical, chemical, biological, or research laboratories in which outstanding work is being done.

CHANGING CONCEPTIONS *of* MAJOR TOPICS *in* HIGH-SCHOOL CHEMISTRY TEXTBOOKS

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SCIENTIFIC progress and research should be reflected in the type and amount of material contained in representative high-school chemistry textbooks published over a period of years. The present study was designed to ascertain the changing conceptions, if any, of major topics in high-school chemistry textbooks from 1913 to 1937, inclusive. It is a recognized fact that the chemical industry of the country has experienced a phenomenal growth, change, and development during this same quarter century. If our high-school chemistry textbooks have kept pace with this progress, they, too, should reflect this trend in the space devoted to the major topics of chemistry. A knowledge of the relative values and predominating trends of the various major topics should be of value to the high-school chemistry teacher, administrator, and textbook writer.

Simmons[1] reports a similar investigation of sixteen general science textbooks published over a period of twenty-four years. For ease of interpretation, the twenty-four years covered in this previous analysis were divided into four equal periods. General science textbooks of four publishers were used for each period. A tabulation was made of sixteen major topics revealing the number of pages and percentage of total space devoted to each of the sixteen topics.

In the present study a tabulation has been made of twenty-five high-school chemistry textbooks, so selected that the copyright date for one only occurs during each of the past twenty-five years, 1913 to 1937, inclusive. An attempt has been made to select only books that are truly representative of the years in which each was copyrighted. By this procedure a representative sampling of high-school chemistry textbooks, one for each of the past twenty-five years, has been obtained. Obviously, by such a procedure it has been impossible to include many leading texts of these several years, since only one was selected for each year, and frequently several books were copyrighted during the same year. Likewise, later editions of many of these textbooks have since been published, but these older editions have been included as being representative of the several years involved. The following twenty-five textbooks, designed primarily for high-school use, have been included in this study.

KAHLENBERG, LOUIS AND EDWIN B. HART, "Chemistry and its relation to daily life," The Macmillan Co., New York City, **1913.**

BLANCHARD, ARTHUR A. AND FRANK B. WADE, "Foundations of chemistry," American Book Co., New York City, **1914.**

IRWIN, FREDERICK C., BYRON J. RIVETT, AND ORETT TATLOCK, "Elementary and applied chemistry," Row, Peterson and Co., New York City, **1915.**

TOTTINGHAM, WILLIAM EDWARD AND JOSEPH WAITE INCE, "Chemistry of the farm and home," Webb Publishing Co., St. Paul, Minn., **1916.**

SNELL, JOHN FERGUSON, "Elementary household chemistry," The Macmillan Co., New York City, **1917.**

DULL, CHARLES E., "Essentials of modern chemistry," Henry Holt and Co., New York City, **1918.**

SMITH, ALEXANDER, "Intermediate textbook of chemistry," The Century Co., New York City, **1919.**

BLACK, N. HENRY AND JAMES BRYANT CONANT, "Practical chemistry," The Macmillan Co., New York City, **1920.**

WILLAMAN, JOHN J., "Vocational chemistry for students of agriculture and home economics," J. P. Lippincott Co., Philadelphia, Pa., **1921.**

NEWELL, LYMAN C., "Practical chemistry," D. C. Heath & Co., New York City, **1922.**

COOK, CHARLES GILPIN, "Chemistry in everyday life," D. Appleton and Co., New York City, **1923.**

GRAY, CARL WILLIAM, CLAUDE W. SANDIFUR, AND HOWARD J. HANNA, "Fundamentals of chemistry," Houghton Mifflin Co., New York City, **1924.**

DINSMORE, ERNEST L., "Chemistry for secondary schools," F. M. Ambrose Co., New York City, **1925.**

BROWNLEE, RAYMOND B., ROBERT W. FULLER, WILLIAM J. HANCOCK, MICHAEL D. SOHON, AND JESSE E. WHITSIT, "Elementary principles of chemistry," Allyn and Bacon, New York City, **1926.**

HOLMES, HARRY N. AND LOUIS W. MATTERN, "Elements of chemistry," The Macmillan Co., New York City, **1927.**

EMERY, FREDERIC B., ELZY F. DOWNEY, ROSCOE E. DAVIS, AND CHARLES E. BOYNTON, "Chemistry in everyday life," Lyons and Carnahan, New York City, **1928.**

FLETCHER, GUSTAV L., HERBERT O. SMITH, AND BENJAMIN HARROW, "Beginning chemistry," American Book Co., New York City, **1929.**

MCPHERSON, WILLIAM, WILLIAM EDWARDS HENDERSON, AND

[1] SIMMONS, "Changing conceptions of major topics in general science textbooks," *J. Educ. Research*, **31**, 199–204 (1937).

GEORGE WINEGAN FOWLER, "Chemistry for today," Ginn and Co., New York City, **1930.**

HESSLER, JOHN C., "The first year of chemistry," Benj. H. Sanborn & Co., New York City, **1931.**

TIMM, JOHN ARREND, "An introduction to chemistry, a pandemic text," McGraw-Hill Book Company, Inc., New York City, **1932.**

BRUCE, GEORGE HOWARD, "High school chemistry," World Book Co., Yonkers-on-Hudson, New York City, **1933.**

BRADBURY, ROBERT H., "A first book in chemistry," D. Appleton-Century Co., Inc., New York City, **1934.**

JAFFE, BERNARD, "New world of chemistry," Silver, Burdett and Co., New York City, **1935.**

BIDDLE, HARRY C. AND GEORGE L. BUSH, "Dynamic chemistry," Rand McNally & Co., New York City, **1936.**

HORTON, RALPH E., "Modern everyday chemistry," D. C. Heath and Co., New York City, **1937.**

These twenty-five chemistry textbooks are the product of twenty separate and distinct publishers and are believed to be a fair sampling of the average texts of the past twenty-five years. Some more or less arbitrary criteria of selection were adopted to reduce the number of contributing sources of data sufficiently to make this investigation practicable. A study of the table of contents of the several textbooks examined seemed to justify a tabulation under twenty-four major topics as contained in Table 1. It is quite evident that textbooks of this type do form a source of objective data, but it is also true that the results are somewhat subjective, since no two investigators analyzing the same materials would distribute them under exactly the same headings. The results of this study have been assembled in Table 1, which includes the number of pages and percentage of total space devoted to each of the twenty-four major topics in each of the twenty-five high-school chemistry textbooks published during the past quarter of a century.

An examination of Table 1 indicates that the size of

TABLE 1

NUMBER OF PAGES AND PERCENTAGE OF TOTAL SPACE DEVOTED TO EACH OF THE TWENTY-FOUR MAJOR TOPICS IN HIGH-SCHOOL CHEMISTRY TEXTBOOKS

Author of Textbook	*Kahlenberg and Hart*	*Blanchard and Wade*	*Irwin, et al.*	*Tottingham and Ince*	*Snell*	*Dull*	*Smith*	*Black and Conant*	*Willaman*	*Newell*	*Cook*	*Gray, et al.*	*Dinsmore*	*Brownlee, et al.*
Copyright Date	*1913*	*1914*	*1915*	*1916*	*1917*	*1918*	*1919*	*1920*	*1921*	*1922*	*1923*	*1924*	*1925*	*1926*
MAJOR TOPICS														
1. Historical and Introductory Material	7 2.2%	11 2.6%	6 1.7%	11 3.1%	10 3.8%	13 3.1%	27 5.3%	8 1.7%	8 2.8%	11 2.2%	4 1.4%	10 2.4%	8 1.4%	12 2.0%
2. Laws and Theory	11 3.4%	102 24.2%	54 15.2%	6 1.7%	42 15.8%	44 10.6%	93 18.3%	58 12.7%	19 6.7%	65 13.2%	15 5.1%	108 25.5%	80 14.3%	44 7.6%
3. Water and Solutions	15 4.7%	20 4.8%	28 7.9%	25 7.1%	7 2.6%	31 7.5%	26 5.1%	12 2.6%	16 5.6%	28 5.7%	12 4.1%	17 4.0%	25 4.5%	34 5.8%
4. Hydrogen	2 0.6%	10 2.4%	11 3.1%	5 1.4%	2 0.8%	7 1.7%	9 1.8%	11 2.4%	1 0.4%	11 2.2%	9 3.1%	5 1.2%	25 4.5%	11 1.9%
5. Oxygen	5 1.6%	25 6.0%	14 4.0%	9 2.6%	18 6.8%	14 3.4%	18 3.4%	12 2.6%	1 0.4%	13 2.6%	8 2.7%	11 2.6%	16 2.9%	15 2.6%
6. Air, Nitrogen, and Nitrogen Compounds	30 9.3%	31 7.4%	22 6.2%	22 6.2%	5 1.9%	27 6.5%	28 5.5%	49 10.8%	21 7.4%	36 7.3%	37 12.7%	8 1.9%	41 7.3%	38 6.5%
7. Halogens	7 2.2%	34 8.2%	24 6.8%	8 2.3%	4 1.5%	14 3.4%	48 9.3%	33 7.2%	3 1.1%	22 4.5%	5 1.7%	11 2.6%	16 2.9%	44 7.6%
8. Sulfur and Its Compounds	8 2.5%	16 3.9%	19 5.4%	9 2.6%	1 0.4%	20 4.8%	26 5.1%	27 5.9%	3 1.1%	26 5.3%	11 3.8%	11 2.6%	28 5.0%	29 4.9%
9. The Phosphorus Group	12 3.8%	— —	10 2.8%	5 1.4%	4 1.5%	10 2.4%	10 2.0%	7 1.5%	3 1.1%	14 2.8%	6 2.1%	9 2.1%	13 2.3%	13 2.2%
10. Boron and Silicon	19 5.9%	— —	7 2.0%	6 1.7%	1 0.4%	12 2.9%	6 1.2%	6 1.3%	1 0.4%	13 2.6%	11 3.8%	14 3.3%	20 3.6%	13 2.2%
11. Carbon and Its Compounds	151 47.3%	52 12.9%	42 11.8%	218 61.9%	141 54.8%	84 20.1%	70 13.6%	75 16.4%	178 62.5%	86 17.6%	99 33.9%	81 19.2%	86 15.4%	84 14.0%
12. The Alkali Metals	11 3.4%	15 3.6%	17 4.8%	10 2.8%	7 2.6%	12 2.9%	5 1.0%	20 4.4%	4 1.4%	16 3.3%	5 1.7%	19 4.5%	24 4.3%	29 4.9%
13. The Alkali-Earth Metals	11 3.4%	15 3.6%	13 3.7%	5 1.4%	3 1.1%	11 2.6%	31 6.1%	15 3.3%	7 2.5%	15 3.1%	9 3.1%	6 1.4%	17 3.0%	16 2.7%
14. Aluminum	7 2.2%	3 0.7%	7 2.0%	3 0.9%	1 0.4%	9 2.2%	10 2.0%	9 2.0%	4 1.4%	11 2.2%	5 1.7%	2 0.5%	13 2.3%	18 3.1%
15. Iron and Steel	10 3.1%	12 2.9%	20 5.7%	3 0.9%	5 1.9%	17 4.1%	15 2.9%	26 5.7%	5 1.7%	24 4.9%	12 4.1%	17 4.0%	32 5.7%	30 5.1%
16. Copper	2 0.6%	3 0.7%	5 1.4%	3 0.9%	1 0.4%	3 0.7%	6 1.2%	7 1.5%	2 0.7%	13 2.6%	3 1.0%	4 0.9%	11 2.0%	12 2.0%
17. Silver and Gold	4 1.3%	2 0.5%	9 2.6%	— —	1 0.4%	6 1.4%	6 1.2%	8 1.7%	3 1.1%	10 2.0%	15 5.1%	9 2.1%	13 2.3%	12 2.0%
18. Other Metals	8 2.5%	19 4.6%	21 6.0%	4 1.1%	4 1.5%	43 10.3%	32 6.3%	23 5.1%	5 1.7%	33 6.8%	26 8.9%	36 8.5%	29 5.2%	46 7.9%
19. Colloids	— —	— —	— —	— —	1 0.4%	— —	5 1.0%	3 0.7%	— —	— —	— —	12 2.8%	2 0.4%	13 2.2%
20. Ionization	— —	28 6.7%	7 2.0%	— —	7 2.6%	15 3.6%	18 3.5%	15 3.3%	— —	17 3.5%	— —	7 1.7%	16 2.9%	16 2.7%
21. Radioactivity	— —	— —	— —	— —	1 0.4%	7 1.7%	4 0.8%	11 2.4%	— —	11 2.2%	— —	7 1.7%	10 1.8%	14 2.4%
22. Gases and Their Measurement	— —	12 2.9%	9 2.6%	— —	— —	10 2.4%	6 1.2%	13 2.8%	— —	9 1.8%	— —	9 2.1%	10 1.8%	12 2.0%
23. The Periodic Law	— —	6 1.4%	8 2.3%	— —	— —	7 1.7%	11 2.2%	9 2.0%	— —	8 1.6%	— —	3 0.7%	11 2.0%	12 2.0%
24. Atomic and Molecular Structure	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	7 1.7%	12 2.2%	22 3.7%
TOTAL	320 100.0%	416 100.0%	353 100.0%	352 100.0%	266 100.0%	416 100.0%	510 100.0%	457 100.0%	284 100.0%	492 100.0%	292 100.0%	423 100.0%	558 100.0%	589 100.0%

TABLE 1 (*Continued*)

NUMBER OF PAGES AND PERCENTAGE OF TOTAL SPACE DEVOTED TO EACH OF THE TWENTY-FOUR MAJOR TOPICS IN HIGH-SCHOOL CHEMISTRY TEXTBOOKS

Author of Textbook	*Holmes and Mattern*	*Emery, et al.*	*Fletcher, et al.*	*McPherson, et al.*	*Hessler*	*Timm*	*Bruce*	*Bradbury*	*Jaffe*	*Biddle-Bush*	*Horton*	*Average*	*Total*	*% of total*
Copyright Date	*1927*	*1928*	*1929*	*1930*	*1931*	*1932*	*1933*	*1934*	*1935*	*1936*	*1937*			
MAJOR TOPICS														
1. Historical and Introductory Material	18	25	15	15	28	15	12	22	14	17	20	13.9	347	2.9%
	3.6%	3.5%	3.4%	2.7%	5.1%	2.7%	2.3%	3.7%	2.5%	2.4%	4.6%			
2. Laws and Theory	27	60	36	80	73	151	79	53	58	84	80	60.1	1522	12.8%
	5.4%	8.4%	8.2%	14.5%	13.4%	27.6%	14.9%	8.8%	10.2%	10.8%	18.5%			
3. Water and Solutions	27	25	6	32	34	31	33	29	26	16	25	23.2	580	4.8%
	5.4%	3.5%	1.4%	5.8%	6.2%	5.7%	6.2%	4.8%	4.6%	2.2%	5.7%			
4. Hydrogen	11	10	6	11	15	1	10	11	13	10	21	9.5	238	2.0%
	2.2%	1.4%	1.4%	2.0%	2.8%	0.2%	1.9%	1.8%	2.3%	1.3%	4.8%			
5. Oxygen	15	11	10	19	20	14	17	19	16	26	17	14.5	363	3.0%
	3.0%	1.5%	2.3%	3.4%	3.7%	2.6%	3.2%	3.2%	2.8%	3.4%	3.9%			
6. Air, Nitrogen, and Nitrogen Compounds	44	32	20	33	39	35	35	42	43	28	16	30.5	762	6.4%
	8.9%	4.5%	4.6%	6.0%	7.2%	6.3%	6.7%	7.0%	7.6%	3.7%	3.7%			
7. Halogens	31	18	13	24	30	1	25	30	29	20	9	20.1	503	4.2%
	6.2%	2.5%	3.0%	4.3%	5.5%	0.2%	4.7%	5.0%	5.1%	2.6%	2.1%			
8. Sulfur and Its Compounds	29	16	12	24	25	16	24	37	28	24	13	19.3	482	4.0%
	5.8%	2.2%	2.8%	4.3%	4.6%	2.9%	4.5%	6.2%	5.0%	3.1%	3.0%			
9. The Phosphorus Group	14	16	2	16	16	1	9	17	3	25	—	9.4	235	2.0%
	2.8%	2.2%	0.5%	2.9%	2.9%	0.2%	1.7%	2.9%	0.5%	3.2%	—			
10. Boron and Silicon	16	12	9	17	18	—	15	19	20	16	3	11.0	274	2.3%
	3.2%	1.7%	2.0%	3.1%	3.3%	—	2.8%	3.2%	3.5%	2.2%	0.7%			
11. Carbon and Its Compounds	92	297	138	88	58	64	77	100	115	178	164	56.4	2818	23.6%
	18.5%	41.3%	31.6%	15.9%	10.8%	11.6%	14.6%	16.7%	20.2%	22.8%	37.5%			
12. The Alkali Metals	16	23	9	24	25	10	22	33	15	20	10	16.1	401	3.4%
	3.2%	3.2%	2.0%	4.3%	4.6%	1.8%	4.2%	5.5%	2.7%	2.6%	2.3%			
13. The Alkali-Earth Metals	14	13	10	18	14	4	16	17	15	17	7	12.8	319	2.8%
	2.8%	1.8%	2.3%	3.2%	2.6%	0.7%	3.0%	2.9%	2.7%	2.4%	1.6%			
14. Aluminum	9	13	4	14	11	2	13	11	14	13	2	8.3	208	1.7%
	1.8%	1.8%	0.9%	2.6%	2.0%	0.4%	2.5%	1.8%	2.5%	1.6%	0.5%			
15. Iron and Steel	23	19	30	21	18	21	24	20	30	27	13	19.0	474	4.0%
	4.6%	2.6%	6.9%	3.8%	3.3%	3.8%	4.5%	3.3%	5.3%	3.5%	2.9%			
16. Copper	6	8	1	6	6	7	7	11	13	8	1	6.0	149	1.2%
	1.2%	1.1%	0.2%	1.1%	1.1%	1.3%	1.3%	1.8%	2.3%	0.1%	0.2%			
17. Silver and Gold	8	12	12	11	10	—	8	17	15	25	2	8.7	218	1.9%
	1.6%	1.7%	2.8%	2.0%	1.8%	—	1.5%	2.9%	2.7%	3.2%	0.5%			
18. Other Metals	44	38	34	46	36	30	20	44	36	116	8	31.2	781	6.5%
	8.9%	5.3%	7.8%	8.3%	6.6%	5.5%	3.8%	7.3%	6.3%	14.8%	1.8%			
19. Colloids	11	14	27	11	5	16	6	9	12	12	1	6.4	160	1.3%
	2.2%	1.9%	6.2%	2.0%	0.9%	2.9%	1.1%	1.5%	2.1%	1.6%	0.2%			
20. Ionization	14	6	16	11	19	43	31	14	19	46	6	14.8	371	3.1%
	2.8%	0.8%	3.7%	2.0%	3.5%	7.9%	5.9%	2.3%	3.4%	5.9%	1.4%			
21. Radioactivity	6	5	3	9	—	18	5	20	14	13	2	6.4	160	1.3%
	1.2%	0.7%	0.7%	1.6%	—	3.2%	0.9%	3.3%	2.5%	1.7%	0.5%			
22. Gases and Their Measurement	8	—	3	—	13	18	19	—	1	15	—	6.7	167	1.4%
	1.6%	—	0.7%	—	2.4%	3.2%	3.6%	—	0.2%	1.9%	—			
23. The Periodic Law	9	6	2	11	13	13	13	14	4	8	8	7.0	176	1.5%
	1.8%	0.8%	0.5%	2.0%	2.4%	2.9%	2.5%	2.3%	0.7%	0.1%	1.8%			
24. Atomic and Molecular Structure	6	40	18	12	18	35	9	11	13	22	8	9.3	234	1.9%
	1.2%	5.6%	4.1%	2.2%	3.3%	6.4%	1.7%	1.8%	2.3%	2.9%	1.8%			
TOTAL	498	719	436	553	544	546	529	600	566	786	436	477.6	11941	100.0%
	109.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			

high-school chemistry textbooks has been consistently increasing during recent years. Ten of the textbooks published during the past twelve years contain more than the average number of pages (477.6), while eleven texts published during the first twelve years covered in this study contain less than the average number of pages for the entire period of twenty-five years. This increased size probably represents a somewhat increased emphasis upon a variety of topics during recent years. A study of the exact number of pages devoted to each of the twenty-four major topics, as listed in Table 1, also substantiates the same conclusion. However, a better comparison of relative emphasis can be obtained by a comparison of the percentage figures.

The twenty-five textbooks contain a total of 11,941 pages of which 2818 or 23.6 per cent. are devoted to a consideration of carbon and its compounds. This topic, therefore, receives greatest emphasis. Second in emphasis are the basic laws and theory of inorganic chemistry with 12.8 per cent. of the total space. A variety of miscellaneous metals occupy 6.5 per cent. Other topics which follow in order are: air, nitrogen, and nitrogen compounds, 6.4 per cent.; water and solutions, 4.8 per cent.; the halogens, 4.2 per cent.; sulfur and its compounds, 4.0 per cent.; iron and steel, 4.0 per cent.; the alkali metals, 3.4 per cent.; ionization, 3.1 per cent.; oxygen, 3.0 per cent.; historical and introductory material, 2.9 per cent.; the alkali-earth metals, 2.8 per cent.; boron and silicon, 2.3 per cent.; hydrogen, 2.0 per cent.; the phosphorus group, 2.0 per cent.; atomic and molecular structure, 1.9 per cent.; silver and gold, 1.9 per cent.; aluminum, 1.7 per cent.; the periodic law, 1.5 per cent.; gases and their measurement, 1.4 per cent.; colloids, 1.3 per cent.; radioactivity, 1.3 per cent.; and copper, 1.2 per cent.

A more detailed study of the percentage tendencies

from year to year reveals a marked increase in the emphasis in recent years on the subjects particularly of colloids, ionization, radioactivity, the periodic law and table, and atomic and molecular structure. While it is true that some items of radioactivity, ionization and atomic and molecular structure represent recent developments, yet the inclusion of these same items in these texts did not follow for several years. There is a very noticeable decrease in the emphasis placed upon the detailed chemistry of the less common metals. The basic laws and theory, mathematical treatment of gas volumes, and the study of carbon compounds continues to hold an important place in recent textbooks.

CONCLUSIONS

In addition to the facts immediately obvious from a study of Table 1, the following conclusions seem to be justified.

(1) Recent high-school chemistry texts are placing an increased emphasis upon the subjects of colloids, ionization, radioactivity, the periodic law, and atomic and molecular structure.

(2) A consideration of carbon and its compounds still retains a predominating position among all major topics.[2]

(3) Recent texts are placing less emphasis upon a detailed consideration of the complex chemistry of numerous metallic elements.

(4) A consideration of the basic laws and theories of inorganic chemistry still occupies a commanding position in recent texts.

(5) Other basic topics as listed show little change in emphasis.

(6) Recent texts contain more practical applications, less technical detail, and yet retain basic and fundamental laws and theory.

(7) Recent high-school chemistry textbooks are increasing in size.

(8) Increased emphasis on major topics is frequently obtained by adding pages, thereby increasing relative percentages, rather than by eliminations of older materials.

[2] DUNBAR, "The organic content of twelve high-school chemistry textbooks," J. CHEM. EDUC., **14**, 115–17 (1937).

THE LABORATORY OF LOUIS PASTEUR

PAUL ASH

Ball High School, Galveston, Texas

EDITOR'S NOTE.—*Mr. Ash was a pupil of Miss Greta Oppe when he undertook the project which he describes here. Other dioramas made by pupils of Miss Oppe were described in* THIS JOURNAL (**13,** 412–14 (1936)).

I had always admired Louis Pasteur and his accomplishments for the furthering of science and prolonging of life. Hence when shown other dioramas in the chemistry laboratory at school, I chose the Pasteur theme. Information about old laboratories and the life of Pasteur were secured from every source with the help of my father who is a laboratory technician at the medical branch of the University of Texas at Galveston. It took me approximately four months to develop ideas and blow the chemical glassware. The glassware and apparatus are replicas of those attributed to Pasteur. In the rear of the laboratory are animal cages with a dog in one, calling attention to Pasteur's wonderful work on rabies.

A DIORAMA OF PASTEUR IN HIS LABORATORY

A STURDY AIR JACKET FOR THE FREEZING-POINT APPARATUS

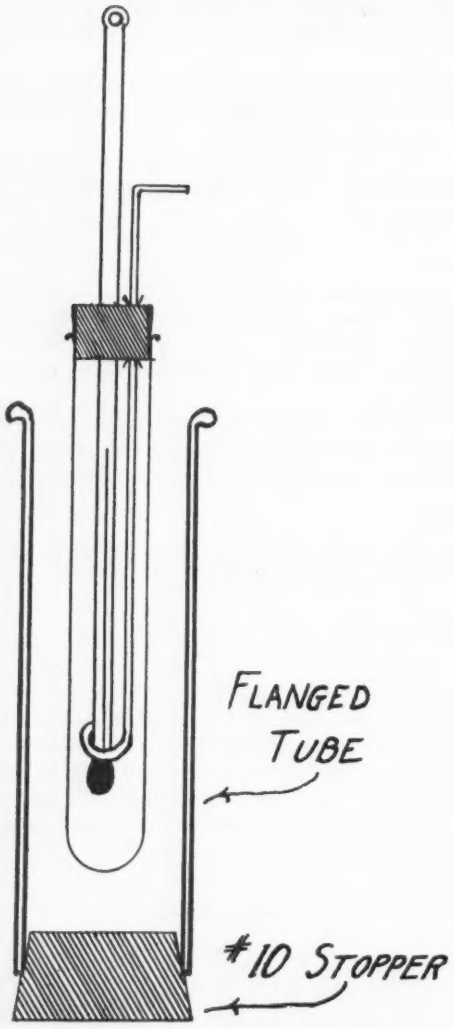
HAROLD G. CASSIDY[1]

Oberlin College, Oberlin, Ohio

IN THE determination of freezing points and freezing-point lowering it is customary to sheath the tube containing the liquid to be frozen in a much larger glass tube which is placed in the freezing mixture and acts as an air-jacket. This jacketing tube is very easily broken. Destruction in elementary classes of a number of these tubes led us to devise a substitute which has served excellently and is practically indestructible.

The device is made from large glass tubing, 45 to 50 mm. outside diameter with a 2 to 2.5 mm. wall. This is cut in lengths of about 16 cm., one end fire-polished and the other flanged slightly. The bottom of the tube is closed with a No. 9 or No. 10 rubber stopper.

[1] Present address: Yale University, New Haven, Connecticut.



AIR JACKET AND FREEZING-POINT TUBE

A completed jacket is shown in the accompanying diagram.

Perhaps a sufficient commentary on their wearing qualities is that the students have nick-named them "bounceables."

A MODIFIED LECTURE EXPERIMENT

WILLIAM J. CONWAY

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THE fundamental law underlying all reaction rates is the law of molecular concentration. Teachers of elementary chemistry have long used for demonstration of this law the familiar reaction liberating iodine from iodate with sulfurous acid.[1] There is, however, one phase of this experiment which has been unsatisfactory, namely, the instability of the sulfite solution. An alternative reaction is frequently carried out for the same purpose, *i. e.*, the exemplification of the law of "mass action," by the precipitation of arsenious sulfide from arsenite by thiosulfate.[2] This clock reaction, in the opinion of the author, lacks the charm and rapidity of color change marking the termination of the induction period that is found in the iodine reaction.

In 1927 Bäckström[3] showed that the photochemical oxidation of sodium sulfite solution is a chain reaction. Later Alyea and Bäckström[4] reported that the action of alcohols in inhibiting the oxidation of sulfite solutions must consist in the breaking of reaction chains in the thermal as well as in the photochemical reaction. Accordingly, it seemed that the addition of a small quantity of alcohol to the sulfurous acid solution used in the above classroom experiment would effectively stabilize the solution and thereby eliminate the necessity of preparing the solution each time it was required. This modification was carried out and very favorable results were obtained. A year-old 0.04 molar solution of sulfurous acid can still be used with considerable success. The induction period is approximately twenty per cent. longer than when the solution is fresh, but standardization before classroom use corrects for the slow change taking place over relatively long periods. Without the inhibiting action of the alcohol on the sulfite, the solution must be prepared as required.

A liter of 0.02 *M* potassium iodate was prepared. The second solution was prepared in the following manner. Five grams of starch were added to one hundred ml. of hot water. After cooling, this was diluted somewhat and 1.26 grams of sodium sulfite dissolved. Ten milliliters of alcohol and 1 gram of salicylic acid were added, and finally sufficient sulfuric acid to make the concentration 0.04 *M* when the solution is made up to one liter. The function of the salicylic acid is to retard the decomposition of the starch. However, on long standing, the latter substance was found to be rather ineffective.

In a number of tests one hundred milliliters of the sulfite solution are added to five hundred milliliters of water. Varying quantities of the potassium iodate solution (thirty-five, fifty, seventy-five, one hundred milliliters) are mixed with this quantity of sulfite. In each case, water must be added to the iodate so that the volume of this solution is one hundred milliliters. In this manner, after mixing the sulfite and iodate, the final volume is seven hundred milliliters. The time between the mixing and the appearance of the blue color is measured by means of a stopwatch. The interval is found to be proportional to the concentration of the reactants.

[1] DANIELS, MATHEWS, AND WILLIAMS, "Experimental physical chemistry," McGraw-Hill Book Co., Inc., New York City, **1934**, p. 150.

[2] FORBES, ESTILL, AND WALKER, *J. Am. Chem. Soc.*, **44**, 97 (1922).

[3] BÄCKSTRÖM, *ibid.*, **49**, 1460 (1927).

[4] ALYEA AND BÄCKSTRÖM, *ibid.*, **51**, 90 (1929).

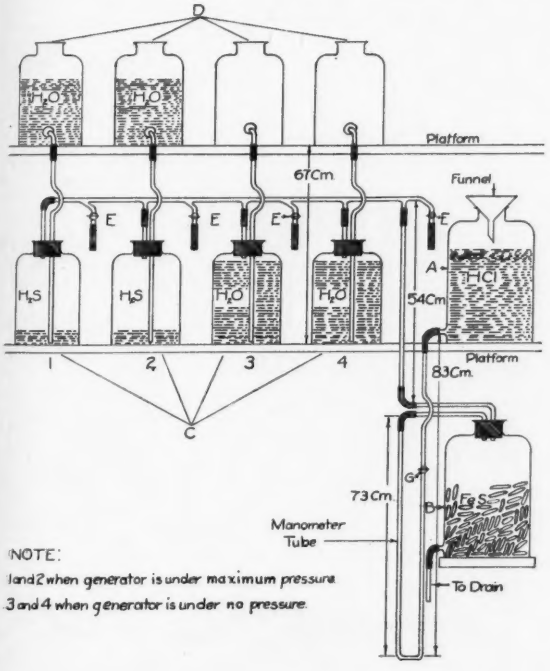
SOMETHING NEW *in* GENERATING HYDROGEN SULFIDE

A. H. PREZIOSO

Youngstown College, Youngstown, Ohio

A COMMON problem confronting the heads of chemistry departments in many schools is the installation of an inexpensive hydrogen sulfide generator, which produces a sufficient supply of gas under constant pressure to meet the demands of thirty or forty students in qualitative analysis.

The generator described is similar to other generators, with a few modifications which have been worked out by Dr. E. D. Scudder, head of the chemistry department at Youngstown College. The apparatus, in the past six years, has given good results. Each year it is rebuilt by a student assistant of the department.



The gas is generated by means of the action of commercial hydrochloric acid on sticks of ferrous sulfide. Excellent results may be obtained by using one part of acid to five parts of water. The acid is stored in bottle *A* (see diagram) and the ferrous sulfide in bottle *B*. When the stopcock *G* is opened, the acid flows into bottle *B*, and releases the hydrogen sulfide. The gas is collected in bottles *C*, and the water is forced into bottles *D*. The length of the manometer tube and the lengths of the tubes leading from bottles *C* to *D* are such that when any amount of gas is generated, the pressure in the manometer tube and in the delivery tubes is quickly equalized. As the students use the gas by means of outlets *E*, the pressure will obviously be diminished; but there is usually enough gas stored to last for some time. However, when the stored gas has dwindled to a low degree, the flow of acid will continue as the process is repeated. Should a greater pressure be built up in bottles *C* than is normally expected, forcing all the water into bottles *D*, the excess gas will escape through the hood. But if the manometer tube were too short, the apparatus would not function as desired. It would not store any residual gas. Instead, the gas may "backfire" into the acid bottle, and the flow of acid not start until the pressure system is practically nil. The residue in bottle *B* is drained from time to time, and the acid bottle recharged.

All the rubber connections are made of high-quality tubing coated with a thin film of paraffin. This is done by immersing the tubing in hot paraffin for a few minutes. The corks are also coated with paraffin and securely fastened with wire and sealed with sealing wax. A little paraffin is added to the sealing wax to decrease the brittleness.

Fifty pounds of ferrous sulfide generate sufficient gas to serve a qualitative class of forty students for one semester. The apparatus should be built in a hood to eliminate any escaping gas. If proper care is given the apparatus, there is practically no odor.

A LECTURE EXPERIMENT FOR DISTINGUISHING LEVULOSE FROM GLUCOSE

EMIL W. ZMACZYNSKI

Pedagogic Institute of Saratoff, Saratoff, U. S. S. R.

TO DISTINGUISH levulose from glucose Scliwanoff's reaction[1] is commonly recommended. The reaction consists of heating the sugar solution with

[1] SCLIWANOFF, *Ber.*, **20**, 181 (1882).

concentrated hydrochloric acid and some resorcin crystals—if a dark red color appears in solution, this is regarded as proof that levulose is present. Glucose should not give this test. By execution of Scliwanoff's reaction we are dealing with inconvenience that also other sugars give the same test, as, for example, cane sugar. For this reason to demonstrate the distinction (difference) between the levulose and glucose, we use the reaction, described by me,[2] between the sulfur and α-hydroxyketones in the following modification and performance.

The small quantities of sugars tested (60–100 mg.) are separately placed in two test-tubes, where the still smaller quantity of sulfur powder (10–15 mg.) is added and in each test-tube 1–2 cm.[3] of pure glycerine with one to two drops of lead acetate solution is poured, whereupon both of the test-tubes are simultaneously heated gently over the flame of burner. In a few seconds the liquid in the test-tube which contains levulose, becomes black; meanwhile the liquid in the test-tube with glucose does not change.[3]

The heating must not be of long duration, else the black color appears in the other test-tube with glucose. The black color, which is characteristic for the described reaction, is caused by lead sulfide formed from acetate and hydrogen sulfide; the latter is evolved in the reaction of sulfur with levulose. Inasmuch as glucose, does not contain the group —CHOH—CO—C, it reacts with the sulfur more slowly and gives the black coloration with delay.

[2] ZMACZYNSKI, *Compt. rend.*, **202**, 668 (1936); *Z. anal. Chem.*, **106**, 32 (1936).

[3] The same results will be obtained if for comparison with levulose instead of glucose cane, milk, and malt sugars are taken.

DRYING APPARATUS FOR FLASKS

FLOYD L. JAMES

Indiana University Extension, Calumet Center, East Chicago, Indiana

FOR quick drying of flasks and other glassware a current of warm, dry air should be supplied at low pressure. An ordinary hair drier provides such a current. A reducer and nozzle may be made to introduce the air into the flask. The whole may be mounted vertically on a tall ring stand and fitted with a foot switch.

The apparatus in use in this laboratory was constructed from a hair drier (*A*) by fitting to the snout a sheet brass reducer (*B*) to which was fastened an eight-inch nozzle (*C*) of one-half inch copper tubing. The reducer was made and the nozzle attached by silver soldering, since it was found that solder melted at the operating temperature. The reducer was simply set over the snout to simplify dismantling for repair or storage.

The drier was mounted vertically at waist height on a ring stand by means of two clamps. An ordinary push button switch (*D*) was set on the base of the stand to insure that the current would be off when the drier was not in use. The Bakelite around the button was filed down to make contact by foot easier.

The students should be supplied with these instructions.

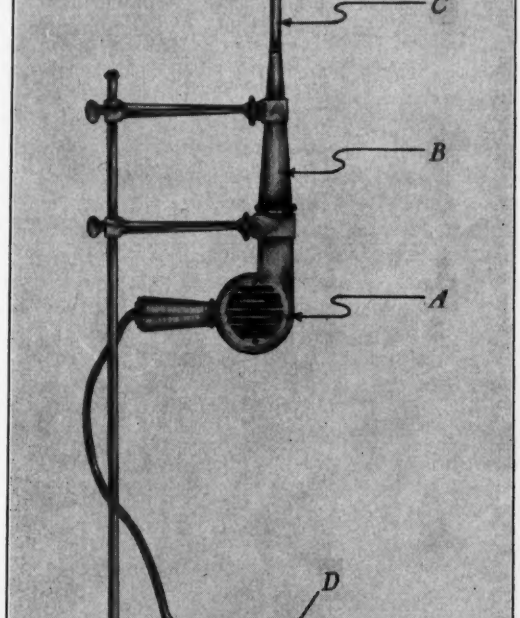
(1) Wash the flask well; if necessary use cleaning solution.

(2) Rinse twice with tap water.

(3) Rinse once with distilled water and allow to drain.

(4) Dry the outside thoroughly with a towel.

(5) Hold the flask by the neck with the opening downward and heat the body of the flask over a moderate flame, freeing all the inner surface from liquid water.



(6) Blow out the water vapor with the flask drier.

(7) Wipe the condensed water out of the inside of the neck.

This inexpensive and effective flask drier will be found particularly useful in the organic laboratory, where a device of this type is often needed but seldom available.

RECENT BOOKS

INTRODUCTORY COLLEGE CHEMISTRY. *Neil E. Gordon*, Professor of Chemistry, Central College, formerly Professor of Chemical Education, The Johns Hopkins University, and *William E. Trout, Jr.*, Professor of Chemistry, Mary Baldwin College. Second Edition. John Wiley and Sons, Inc., New York City, 1940. ix + 753 pp. 159 figs. 15 × 23 cm. Net, $3.50.

This text is a real contribution in its field. This is because it is based on the truly original plan of building experimental exercises into the body of the text. As a result, the text is a teaching tool, rather than a reference book. By way of illustration, a neophyte student turning to his first assignment, water, is, after the first paragraph, sent into the laboratory to determine the percentage of water in milk, or to observe a lecture-demonstration of it. Now chemistry is a laboratory, not an armchair science, so that this experimental approach is basically sound in giving the student the proper scientific attitude. It is good pedagogy; and the authors are to be congratulated for reëmphasizing this novel approach in elementary chemistry.

Part I: Non-metals; and Part II: Metals, are subdivided into unit topics called Books; which in turn are separated into Sections; thus Part I, Book II: Some Fundamentals of Chemistry includes Sections on Fundamental Laws, Gas Laws, Molecular and Atomic Weights, Formulas, Equations and Calculations. The treatment of the non-metals conforms with orthodox general chemistry sequence. The treatment of the metals, however, is unique. For example, Book IV: The Ammonium Sulfide Group, contains the Sections (I) The Aluminum Family; (II) The Chromium Family; (III) The Manganese Family; (IV) The Iron-Platinum Family; (V) The Zinc Family; and (VI) Qualitative Analysis of the Ammonium Sulfide Group. By this device the teacher may discuss both the periodic and analytical relationships of the metals.

An abundance of questions and problems have been appended to each section, together with references to articles in the JOURNAL OF CHEMICAL EDUCATION.

Forty pages of new material discuss, with clarity, atomic structure, isotopes, valence bonds, oxy-compounds of the halogens (seven pages), and foodstuffs, together with a thorough treatment of the Debye-Hückel and the Brønsted theories of solutions (eight pages). Several new tables have been added or brought up-to-date. The remaining seven hundred pages are practically unchanged from the first edition. This is unfortunate in the case of certain older industrial processes, such as the arc and cyanamide processes, which receive disproportionate attention at the expense of newer industrial processes and advances in special fields such as in photochemistry and kinetics.

One hundred seventy-seven experiments have been carried over, unaltered, from the first edition, two dropped, and eleven added. These latter include the fixation of nitrogen by magnesium, titration in glacial acetic acid, preparation of chlorine monoxide and hypochlorous acid, and cellulose, starch and foodstuff experiments.

There are nearly one hundred new diagrams and pictures. The publishers should have taken more pains with a few of the latter; at least half a dozen of the plates, apparently taken from the 1925 edition, are much the worse for wear. But the printer has more than atoned for this by his careful and generous spacing of material, structural diagrams, and tabulations.

There is a certain historical charm in contrasting this second edition with its first edition published a decade and a half ago by the World Book Company. This is especially true because the authors have faithfully replaced portraits of famous scientists with more recent ones. The March of Time is recorded in a number of these portraits: Rutherford has exchanged the dash of youth for dignity and an honorary hood; W. D. Harkins has turned from a 1928 fog-track apparatus to a 1940 electron-diffraction camera focused on monomolecular films. Baekeland, alone, has escaped the ravages of time and a second edition as, in an interesting candid camera shot, he stands in the same laboratory holding aloft the same flask of phenolic condensate as in 1925.

No teacher of general chemistry should feel his education complete until he has examined this text to see how skilfully experimental material can be blended into facts and theories to a degree that can seldom be achieved by a separate manual and text.

H. N. ALYEA

PRINCETON UNIVERSITY
PRINCETON, NEW JERSEY

A TEXTBOOK OF QUANTITATIVE INORGANIC ANALYSIS—THEORY AND PRACTICE. *Arthur I. Vogel*, D.Sc. (Lond.), D.I.C., F.I.C., Head of Chemistry Department, Woolwich Polytechnic: Lately Beit Scientific Research Fellow of the Imperial College. Longmans, Green and Co., London and New York City, 1939. xix + 856 pp. 143 figs. 13.5 × 21.5 cm. $5.00.

The author has aimed to provide a complete and up-to-date text of the theory and practice of quantitative analysis: simple and detailed enough for the elementary student, yet comprehensive enough for the advanced student or practical analyst. In his point of view, choice of material, and style he has succeeded admirably in this task.

The first one hundred ninety-five pages are devoted to the theoretical basis of quantitative analysis. A general treatment of the ionization theory, solubility products, complex ions, and hydrolysis is followed by applications to volumetric analysis. This section contains a good and up-to-date discussion of the theory of neutralization indicators, as well as the practical usefulness of the newer mixed indicators. The thory of reactions involving precipitation and complex formation also is discussed. The treatment of oxidation–reduction reactions deals with chemical indicators as well as potentiometric methods of determining the endpoint. The theory of gravimetric analysis includes colloidal behavior, coprecipitation, and electro-deposition.

The second section of eighty-five pages takes up general experimental technic—the use of the balance and the standardization of weights, reagents, sampling, volumetric apparatus and its standardization, and the technic of gravimetric analysis. This section contains specific information and good illustrations, which should enable the student to make a wash bottle, prepare a Gooch crucible, burn off a filter paper, or use a platinum crucible with a minimum amount of supervision and of disaster.

The next two hundred pages deal with volumetric analysis. The choice of material is varied and the experiments are well described, both in theory and in practice. A dozen determinations based on neutralization reactions are followed by twenty involving precipitation and complex formation. Three-quarters of the space is devoted to oxidation–reduction reactions, including permanganate, dichromate, ceric and manganic sulfates, potassium iodate, potassium bromate and chloramine-T as oxidants and titanous salts, zinc and other amalgams as reductants. The many ramifications of iodimetry and iodometry are also given in detail.

Gravimetric analyses take up the next two hundred pages. After a few simple determinations, such as water of hydration, chloride, and sulfate, the systematic gravimetric determinations of fifty cations and twenty-six anions are presented. These are followed by nine binary mixtures and ten complex mixtures, such as brass, steel, and portland cement.

A thirty-page discussion of colorimetric methods, with many excellent illustrations, is followed by applications to the determinations of fifteen elements or radicals.

The last chapter devotes forty pages to gas analysis. The

general methods are discussed, the necessary apparatus is well described and illustrated, and five different analytical determinations are given.

An appendix of seventy pages contains logarithms, table of constants, and much other useful information, including a list of analytical reagents and analyzed samples. Sources of these materials are listed in this country as well as in England. The same is true of apparatus and materials frequently noted throughout the book. A thoroughly adequate index completes the book.

This book should find a place in any but the briefest elementary course, and serve for much subsequent advanced work. It is written in a lucid style, easy for the student to follow, and it contains the illustrations and specific directions which help him to develop his analytical technic. The typography and arrangement is attractive, and the paper and binding are good. A teacher of an elementary course would certainly wish to supplement the work with many problems in chemical arithemtic, none of which is included in this volume. The advanced student would do well to extend the study of the determination of single ions to a more general consideration of the separation of the components of mixtures, such as Lundell and Hoffman present in their OUTLINES OF METHODS OF CHEMICAL ANALYSIS. Reference to this and other supplementary material is found in the appendix, in the well-organized list of books and journals dealing with different aspects of quantitative analysis. Further elaboration of these points is beyond the scope of even such an inclusive book. The author has fulfilled his ambitious program well and has written a useful book, covering a wide field of application.

FRANK T. GUCKER, JR.

NORTHWESTERN UNIVERSITY
EVANSTON, ILLINOIS

INDUSTRIAL SOLVENTS. *Ibert Mellan*. Reinhold Publishing Corporation, New York City, 1939. xi + 480 pp. 267 figs. 126 tables. 15 × 23 cm. $11.00.

This is a reference book written from the viewpoint of the technical man in the field of lacquers, plastics, and related products. The various solvents are discussed chiefly in relation to their dissolving action on cellulose and its derivatives, gums, natural resins, and other lacquer constituents. There is, however, some discussion of other applications such as dry cleaning, extraction, and the like.

The real meat of the book is contained in Chapters 8 through 16 which cover three hundred twenty pages in themselves. In these chapters the various solvents are grouped according to their chemical structure, *e. g.*, hydrocarbons, alcohols, aldehydes, acids, ketones, and so forth. Each solvent is discussed individually, its uses and solvent characteristics are outlined, and its physical constants are given in detail. One very useful feature is that the various trade names for each compound are given, thus furnishing the lacquer chemist with information as to the type of compound which is being advertised for this or that purpose in the trade journals.

The book is filled with tables and graphs giving an enormous amount of information on specific heats, viscosities, vapor pressures, evaporation rates, specific gravities, and solubilities. This collection of data is alone worth several times the price of the book to anyone who uses solvents a great deal. In addition to these data, there is an excellent chapter on plasticizers, and a chapter on the fundamentals of graphical expression and interpretation which explains the mathematics of the various types of curves used in expressing the properties of solvents and solvent mixtures.

Aside from the practical information just mentioned, the first seven chapters are devoted to a more or less theoretical discussion of the properties of solvents such as vapor pressure, evaporation rate, viscosity, inflammability, toxicity, and so forth, and this material is of general interest to chemists, even though they may not be users of great amount of solvents.

One rather minor criticism that might be made is that while the author's theories as to solvent action are set forth in the first three chapters (especially the first) the discussion is not very logical or clear. As a result, it requires real mental labor to get a coherent picture of the material presented. If this defect were remedied, the book could, to some extent, find use as a text in college work, and would be of value to students who planned to pursue an industrial career. However, this deficiency does not affect its value as a reference volume.

EDMUND W. LOWE

THE EDWAL LABORATORIES, INC.
CHICAGO, ILLINOIS

THE DETECTION AND IDENTIFICATION OF WAR GASES. *Ministry of Home Security, Air Raid Precautions Department*. Chemical Publishing Co., New York City, 1940. iv + 53 pp. 14 × 22 cm. $1.50.

This little book is a service manual for the British G. I. O. (Gas Identification Officer). This officer is not necessarily a chemist but should have some technical training; he must be alert and have sound judgment. When a gas attack is made the G. I. O. must hear about it, get there at once, identify the gas, determine the extent of the danger zone, do what is to be done, and make a report. Details are given of the subjective methods of identifying gases, that is, by one's five senses aided by observations of the effects of the gas on people or on objects. In most cases this will be the only evidence that can be secured, but the G. I. O. carries a sampling and testing outfit packed in a box nine by four and one-half by four and one-half inches. If possible, he is to secure samples which can be examined further or sent to the Laboratory.

As information for the G. I. O. and for any who may be concerned, the physical and chemical properties of the common war gases are given and their physiological effects described. A general table gives for each gas, the name, odor, minimum perceptible concentration in milligrams per cubic m., nature of the effect, the intolerable concentration, and the "fatal product." This is the concentration in milligrams per cubic m. times the duration of exposure in minutes for fatal results.

The book is written for a practical purpose and is well adapted to it.

E. EMMET REID

203 EAST THIRTY-THIRD STREET
BALTIMORE, MARYLAND

THE CYCLOTRON. *W. B. Mann*, Imperial College, London. Chemical Publishing Co., New York City. 1940. xi + 92 pp. 31 figs. 10 × 16 cm. $1.50.

This little book on the cyclotron and cyclotron technic would be instructive to any student of the biological and physical sciences who has mastered the principles of elementary physics. The evident importance of the cyclotron to all these sciences seems a sufficient justification for a book of this scope. Assuming that the book is addressed to comparatively elementary students of physics and chemistry, who are not necessarily familiar with nuclear physics, and to more advanced biologists, there can be little quarrel with the text. It gives a clear and well-written account of the resonance principles which multiply the applied voltage a hundredfold, and of the focusing action which holds together a narrow beam of ions over a path of hundreds of meters. The more difficult problem of describing the apparatus in detail is satisfactorily handled, although these chapters might be somewhat condensed.

From the point of view of the reader of little background, to whom this book should be most useful, there seems to be a great lack. Nowhere is it stated emphatically that the cyclotron is simply a tool of nuclear physics, and that nuclear physics offers the possibility of as great advances in the knowledge of the nature of matter or chemistry and spectroscopy have already made. Without a definite statement of the end in view the book seems to be an exposition of art for art's sake. A final chapter, which might profitably be greatly expanded, does show uses of the products of nuclear reactions in chemistry and biology.

HENRY W. NEWSON

THE UNIVERSITY OF CHICAGO
CHICAGO, ILLINOIS

DR. OTTO REINMUTH

EDITOR OF THE JOURNAL OF CHEMICAL EDUCATION (1933–40)

« « « « « EDITOR'S OUTLOOK » » » » »

OUR FRONTISPIECE this month bears testimony to a long-continued effort, perhaps too little appreciated by the Journal and the Division of Chemical Education. There is a measure of poetic justice in this. Dr. Reinmuth has been putting the pictures of other people on this page for eight years or more now, and it is time that the tables were turned. So we turn them.

Otto Reinmuth was first associated with the JOURNAL OF CHEMICAL EDUCATION in 1925 when, as a graduate student at the University of Maryland, he became an assistant to the editor, Dr. Neil E. Gordon. Later he moved up to the position of associate editor, which he held until the retirement of Dr. Gordon in 1932. At that time the affairs of the Journal reached their first important turning point. The generous subsidy of the Chemical Foundation, which had long been an important source of support, was discontinued, and it was thought that the Journal had reached sufficient maturity to be able to live by its own efforts. That it was able to do so, during a period of general depression, was in no small measure due to the untiring efforts of Dr. Reinmuth, who had undertaken the editorship. Not only did it survive, it strengthened its reputation enormously in the field of chemical literature. Its value as "A Living Textbook of Chemistry" increased steadily; every new published textbook found it a necessary source of reference; it became indispensable to those following the history of chemistry. Some lean years passed, leaner, perhaps, than anyone but the editor will ever know. But he jealously guarded the Journal's good name, refusing to cheapen it in any way. If the Division is proud of its periodical—as it should certainly be—it is due almost entirely to the efforts of two men, one of whom is Dr. Reinmuth. (Some other time, maybe, we will tell you about the other man.)

Perhaps the members of the Division and the readers of the Journal have not known their editor well enough to appreciate him fully. He has been too reticent for his own good, but his more intimate friends know him as a genial and interesting companion, considerate, and possessed of a quiet but delightful sense of humor. At the same time, his personal influence upon the field of chemical education will be no less profound for being largely unrecognized.

When the editorial office was moved to Chicago, he became associated with an old friend, Professor Morris S. Kharasch, with whom he has since been collaborating on a textbook of organic chemistry. He also became the managing editor of the *Journal of Organic Chemistry*, upon its foundation. What time he could snatch from his editorial duties he devoted to organic research, for which purpose he was given a special appointment to the staff of the University of Chicago. In the last two or three years he has done a great deal of work on pharmaceuticals and has to his credit a number of worthwhile contributions to chemotherapy. It is the growing importance of this phase of his work that has at last led him to retire from the editorship of the JOURNAL OF CHEMICAL EDUCATION. It is a loss to the Division and the Journal, but we can appreciate his desire for more time to devote to his research, and we prophesy a brilliant professional future.

UNDERTAKING the Editorship of the JOURNAL OF CHEMICAL EDUCATION is at the same time a responsibility and a challenge. Probably everyone who has inherited the administration of a "going concern" like this has the same mixture of feelings; a desire to conserve safely the gains of the past, enlivened by the optimistic thought that perhaps a good thing can be made even better. Two sound and successful editorial terms have preceded this one, and we only hope that when we, in our turn, hand over the shears and wastebasket to our successor we can do so with as much pride in our own accomplishment as can justly be felt by our two predecessors.

The present seems to be an appropriate time to make certain general observations about the Journal which are not original, but which, like our white tie and tails, must be dusted off and paraded every now and then. The first is the reminder to all the members of the Division of Chemical Education that this is *their* journal. And we shall try to make it increasingly so. Considering this relation, it seems only fair to expect one hundred per cent support from the members of the Division. (Well, say ninety-five per cent, anyway.) Unfortunately, those few to whom this comment is pointedly directed are not likely to see it.

Second, we fully realize the desirability and impossibility of pleasing everyone all the time. Our readers have a wide diversity of interests. It is illuminating, and at the same time disconcerting, to run over a list of the various reader-interests, several of which have been compiled from questionnaires in the past. We must reckon with the fact that while the great majority of our subscribers are teachers or students of chemistry, and primarily concerned with the method and content of teaching and learning chemistry, still we have a neat minority of readers whose interest cannot be described as "professional," at least in the educational sense. Consequently, our policy shall be to conduct the Journal primarily for teachers and students, without losing sight of the fact, however, that Chemical Education has its broad aspects, quite outside any formal educational agency, even to the end of educating a somewhat reluctant lay public. (N. B. to the

Editor: Elaborate this point some time.) We will try to be eclectic in the choice of material, and while not riding our own hobbies will give an opportunity to others to ride *theirs*, at least to the extent to which they seem healthy and sound of wind. And if we are discovered inadvertently wandering down blind byroads which we should perhaps not be treading, or blindly missing the highways which lead somewhere, the United States mails are free and open to everyone, and you never know what editorial dividends you may draw from the investment of three cents in a postage stamp. The *percentage* return might be even greater from a one-cent postcard. In fact, we especially would like to encourage the greater use of the correspondence column in the Journal.

We want to increase the effectiveness of the Journal to those who feel that their chemical education is in the relatively elementary stage. And this includes, let us reassure you, many who are growing gray in the service of chemistry. We will continue to devote a part of our effort to chemical education at the high-school level. And at the other end of the scale we will try to keep the Journal within the comprehension of the student who has gone no further than elementary physical chemistry.

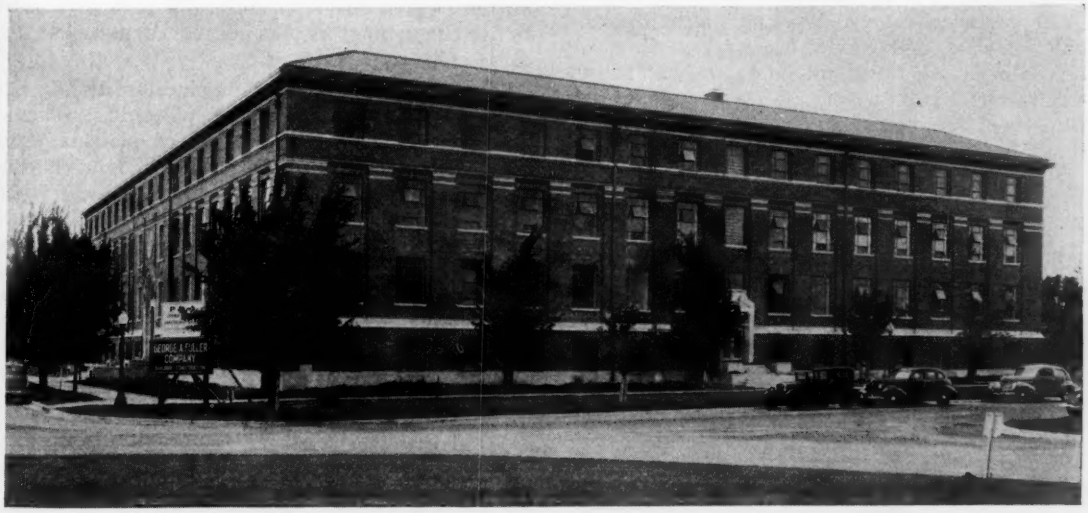
Finally, to authors, we promise as rapid consideration of their efforts as possible, and we will not accept manuscripts far in advance of our publication schedule.

ON THE contents page of this issue will be seen the result of a complete editorial reorganization. This will introduce to our readers a new group of Associate Editors, to replace the cumbrous organization of departmental and contributing editors of the past. To the latter we extend our grateful thanks for their long coöperation. We do not feel that we are passing them completely out of service by removing their names from the title page. The new board of Associate Editors will be an active group, who, among other things, will serve as "outposts" of the editorial office in the various parts of the country.

TWO youngsters of our acquaintance were playing on the beach recently when the rising tide began to menace the sand-structures resulting from two hours of rapt attention. The older boy, himself busy at some distance, was directing the work of repair. Urging his younger helper on to a greater show of activity, his voice piped up: "Get started, Laurie. It doesn't make any difference where you are, as long as you just get started."

Ye Gods! "Out of the mouths of babes and children." Whether it is scientific research, national defense, or just the ordinary, everyday business of living, it doesn't make any difference where you are, as long as you just get started. It is immaterial where you wake up each morning, as long as it isn't in exactly the same spot you were yesterday, and the day before, and the day before that. However, the game is not lost, for we believe inquiry would show that more progress has been made in the study of abrasion-resistance in shoe-soles than in pants-seats. This must surely have been the result of necessity.

But to come back to the start, we would like to think there was significance in the fact that the two youngsters in this episode were the offspring of prominent chemists.



THE NEW CHEMICAL AND METALLURGICAL ENGINEERING BUILDING AT PURDUE UNIVERSITY, WHICH IS REPORTED TO INVOLVE SEVERAL NEW FEATURES OF DESIGN AND EQUIPMENT

LETTERS

Encyclopedia of Chemical Reactions

To the Editor:

In the October, 1933, issue of the JOURNAL OF CHEMICAL EDUCATION was published an article describing at length my proposed "Encyclopedia of Chemical Reactions." That article elicited widespread attention and offers of coöperation and help came from many quarters. Brief notes about the Encyclopedia were published in a number of journals.

The abstracting of chemical reactions from the chemical journals was begun by Miss Kathryn Huffman and continued by a corps of fifteen other abstractors, including some in foreign countries. Nearly all of the abstracting work was voluntary. Over six thousand reactions have thus far been submitted on $4'' \times 5\frac{1}{2}''$ cards, and filed.

It is for the reason that many people have written me regarding the progress of the Encyclopedia and inquired as to the probable date of its publication that I am writing you. No publisher has yet been obtained and no fixed date of publication arranged. Two publishers of reference works who were approached have expressed interest in the work and promised careful consideration.

Since the Encyclopedia will include the inorganic reactions published in the chemical journals in all languages the work would seem, at first glance, to be well nigh impossible. However, it goes much faster than at first anticipated, for most of the literature deals with the uses or the physiological or physical properties of compounds, while the Encyclopedia will record the results of chemical change only, and will be the most complete and accessible reference work dealing with inorganic chemical transformations. It will become especially useful to men who are prosecuting research in all fields of chemistry.

Dr. Wilhelm Segerblom has done invaluable service by abstracting the Scandinavian chemical journals, in addition to looking over all journals in related fields, and has submitted more than 1500 reactions. In order to complete this work we need other volunteers for the abstracting of the remaining journals, including the German and French.

Someone reading this may be able to suggest a plan by which the abstracting could be financed and expedited. One of the associate editors of Gmelin's "Handbuch," and a linguist of unusual ability, is now in this country and has consented to become a collaborator if his expenses can be met. I shall deeply appreciate any encouragement or aid for the work.

C. A. JACOBSON

WEST VIRGINIA UNIVERSITY
MORGANTOWN, WEST VIRGINIA

Chromite in the Philippines

To the Editor:

"No prospect of a chrome shortage threatens, but unfortunately commercially workable deposits *are all situated in the world's most inaccessible* outposts—New Caledonia, Rhodesia, India, Russia and Turkey." The italics are mine. The quoted statement is from Anon.[1] and A. T. B.[2]

It is surprising that the large deposits of chromite in the Philippines were overlooked so completely, and particularly in view of the considerable mention given to them by A. L. Smith,[3] United States Bureau of Mines.

According to Mr. Geo. O. Scarfe, Chief Engineer of the Consolidated Mines, Inc., Manila, the Masinloc Chromite Deposit consists of actually proven reserves of ten million tons of chromite ore. The average composition and grade of the ore is as follows:

Cr_2O_3	32%	Al_2O_3	26%
FeO	15%	CaO	1%
SiO_2	5%	MgO	18%
Average Cr to Fe		2:1	

The Masinloc Chromite Deposit is situated twenty-five kilometers inland from the coastal town of Masinloc, Zambales Province, Luzon. A reinforced concrete pier has been constructed with thirty-five feet of water at the wharf head at mean low tide. This permits the loading of ocean-going vessels at all seasons of the year.

Recently the Masinloc Mine has been put into production. Present shipments are from four thousand to five thousand gross tons per month under long term contract.

Besides chromium the Philippines are rich in other minerals. Gold occupies first place in production. Iron ore[4] exists to the extent of perhaps several hundred million tons. Copper, lead, molybdenum, zinc, titanium, manganese, small quantities of platinum and antimony occur. Asbestos, short fibered of the chrysotile variety, was commercially exploited several years ago. Coal exists in commercial quantities in many parts of the islands. Crude oil, however, does not appear to exist in other than small amounts.

ROLLIN G. MYERS

CAVITE, PHILIPPINE ISLANDS

[1] *Chem. Industries*, **10**, 23–6 (Jan., 1937).
[2] J. CHEM. EDUC., **14**, 396 (Aug., 1937).
[3] A. L. SMITH, "Chromium, general information," Information Circular, Bureau of Mines, April 30, 1932.
[4] According to the Director of Mines, the iron ore in Suragao, Mindanao, is estimated at one billion tons. This is associated with nickel.

EARLY PENNSYLVANIA POTTERY

R. D. BILLINGER

Lehigh University, Bethlehem, Pennsylvania

THE earliest pottery made in Pennsylvania was produced before the white man appeared. Indian ware which is occasionally found in caves, excavations, and graves shows that the red men, like most primitive people, made utensils of clay. And they did a fairly creditable job when we consider their lack of simple mechanical aids. As to whether or not the Indians influenced the making of earthenware by the colonists there is grave doubt. The simplicity of certain Pennsylvania slipware decoration might show a slight resemblance to Indian signs. Their greatest aid was felt in helping Penn's followers to locate suitable clay as a raw material.

This paper, however, deals only with the potters of the colonial period who settled in the southeastern section of this state. They were chiefly of German origin. They made earthenware objects needed by the colonists—dishes, bowls, jugs, tiles, pipes, etc. Later they produced artistic plates, toys, and images. These early potters worked in small establishments during the era 1750–1850. About fifty such tradesmen have left some record of their work. Their total number probably never exceeded two hundred. After 1850 the numbers engaged in the trade dwindled, but the influence of the early workers has not been lost entirely.

Almost a century before pottery was produced in Pennsylvania there were beginnings elsewhere in the colonies. Spargo (*1*) credits Salem, Massachusetts, with a potter, John Pride, in 1641. We know that there were glassworkers and probably also potters in Virginia prior to this date. The earliest dated piece of slipware pottery produced in Pennsylvania shows the year 1733 (*2*).

GERMAN POTTERS

German emigrants from the Rhineland came to Pennsylvania in large numbers from 1683 to 1775. They came first to the region about Philadelphia, then pushed farther out into the beautiful hills of some ten counties which lie within a hundred-mile radius. They were a mixture of rich and poor, but generally a sturdy, religious folk—Mennonites, Moravians, Schwenckfelders—who sought freedom and fortune in Penn's Woods.

Among the tradesmen were potters who practiced the old art of making earthenware—chiefly redware. Much of this was undecorated and made for utilitarian purposes. The most prized pieces, however, which are still preserved, are those designated as slipware and sgraffito ware. Slip-decorated earthenware was made extensively in Germany and England, with slight variations, during the seventeenth and eighteenth centuries. The art was fostered, if not improved, here in America. Meanwhile in Germany it was slowly replaced after the discovery of porcelain—similar to the Chinese—by John Frederic Böttger in 1710. Some early attempts in this direction were also made in Philadelphia, as will be recorded later in this article.

CLAYS AND MATERIALS

Pennsylvania is well supplied with clays and shales for the production of many ceramic products. Surface clays, available in all sections of the state, were used in the early days (*3*).

Certain well-known sources were known to the pot-

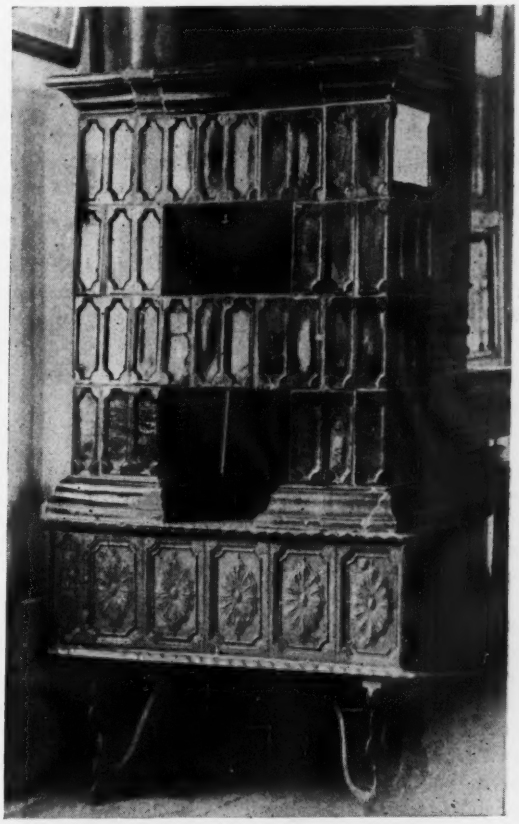


FIGURE 1.—TILE STOVE IN MORAVIAN MUSEUM, NAZARETH, PA. MADE IN BETHLEHEM, PA., BY LUDWIG HUEBNER

ters. Lewis Evans (*4*), a contemporary writer and map maker, cites one region known in 1753.

"The greatest vein of clay for bricks and pottery begins near Trenton Falls, and extends a mile or two in breadth on the Pennsylvania side of the River to Christine, then it crosses the River and goes by Salem. The whole world cannot afford better bricks than our Town is built of."

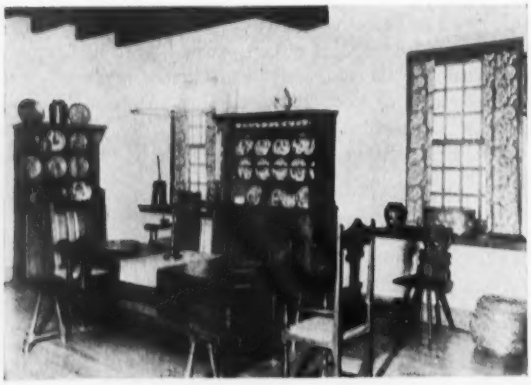


FIGURE 2.—HALL OF THE MÜLLER HOUSE IN PENNSYLVANIA MUSEUM OF ART, PHILADELPHIA, PA.

Another location frequently mentioned as a clay source was Falckner's Swamp. This was a tract of meadow land on the Manatawny Creek in New Hanover Township, Montgomery County. It was part of a tract of 2975 acres which the brothers Daniel and Justus Falckner had obtained from William Penn. Daniel Falckner's written accounts of the new country had stimulated German immigration in the early eighteenth century. Lead ores used in glazing were obtained from several places. Galena was mined at New Britain in Bucks County and near Phoenixville in Chester County.

PRODUCTS MADE

Among the earliest products made were materials used in building construction—bricks and tiles. The latter were used in roofing and in the early tile stoves. Roof tiles were commonly used in the transition period between thatched roofs or wooden shingles and the slate era which began in 1805 (*5*). "Brickeries" were mentioned by William Penn in Philadelphia in 1685.

A map of Bethlehem (*6*) drawn in 1761 shows the location of a "Brick Kill" north of the settlement along the Monocacy Creek. Tile stoves were used even earlier. In October, 1743, Ludwig Huebner, the potter "in the Swamp," had come to set up the first tile stove in the chapel (*7*). Later Huebner located in Bethlehem and became the village potter for over thirty years. Stoves, like Figure 1 which is still preserved in the Moravian Museum of Nazareth, Pa., were supplied to the Continental Army during the Revolution. Huebner and several other local potters also made jars, bowls, and clay pipes.

Alleman (*8*) has analyzed some of the clay roofing tiles made in Bethlehem.

ANALYSIS OF CLAY ROOFING TILE

	Sample 1	*Sample 2*
Total silica	69.49	69.51
Alumina	22.39	22.37
Ferric oxide	3.99	3.40
Lime	0.119	0.120
Magnesia	3.09	3.01

A few published analyses of clays of Northampton County agree reasonably well with these.

Earthenware utensils which constituted the bulk of the products of the old German potters were studied and collected by Barber. These included cooking pots, apple butter pots, flower pots, jugs and jars for sundry uses, coffee and sugar bowls, pitchers, mugs, vegetable and meat dishes, pie plates (poi schissel), shaving basins, vases and toys. In addition there were many specialties which today are made of glass, porcelain, or plastics. A large majority of this material was made in Bucks and Montgomery counties. Splendid examples of these early products are displayed in the Pennsylvania Museum of Art in Philadelphia (Figure 2), in Doylestown, and in Harrisburg.

In Figure 2 is reproduced a hall from one of the better homes in Lebanon County. Here one sees the display cupboards with local pottery and also the gay Staffordshire ware called "gaudy Dutch" which was shipped from England (1790–1840) to supply the desire for colorful show plates.

METHODS EMPLOYED

The term earthenware applies to all ceramic products which are opaque to light. The redware of the German

FIGURE 3.—SLIPWARE (RIGHT) AND SGRAFFITO DISHES (LEFT) IN PENNSYLVANIA MUSEUM, PHILADELPHIA, PA.

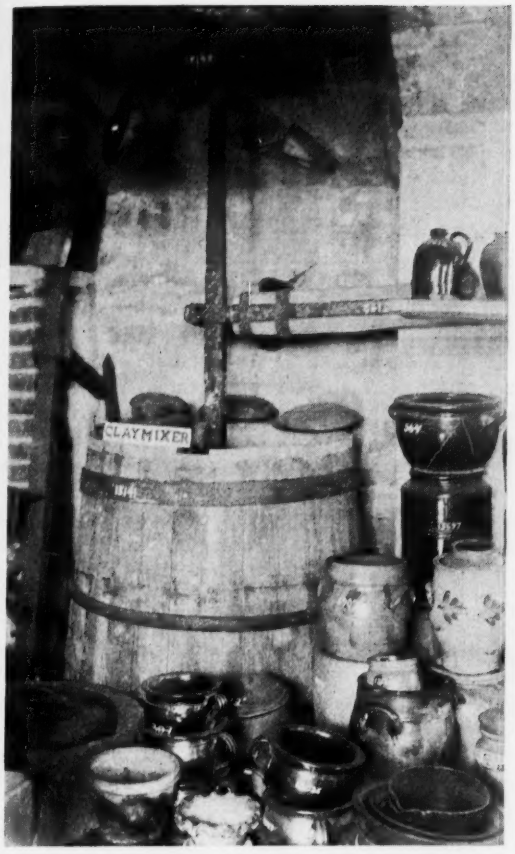


FIGURE 4.—CLAY MIXER AND POTTERY PRODUCTS. BUCKS COUNTY HISTORICAL MUSEUM, DOYLESTOWN, PA.

potters was not dainty. In fact there is a certain crudity about much of it which recalls the primitive. But there was strength and simplicity. The products bespeak the simple methods employed. The steps followed were only the minimum necessary. A modern ceramic engineer would classify them as: (1) procuring raw materials, (2) grinding and preparation of clay, (3) shaping, (4) drying, (5) glazing, (6) firing. For the simplest wares glaze was sometimes omitted. The more elaborate dishes and jars received special decoration, *e. g.*, slip and sgraffito ware.

The potter was careful in his selection of clay. When a bed was located he removed the top soil and hauled his material to his crude clay mill. This was a large wooden tub (Figure 4) about five feet in diameter and four feet high. In the center was a movable post with knives attached to break up the clay. A beam attached to the post top could be turned by hand, or more often by horse if the batch was large. Water was applied to the mass and the churning continued until the mass was soft enough to the potter's touch. This putty-like material was then stored in the cellar or in a room adjoining the pottery. A low fire was kept in the storeroom to prevent freezing, but not so hot as to cake the clay.

SHAPING

Next came the shaping on the potter's wheel. A simple wheel is shown in Figure 5. A flat disc of hard wood was made to rotate on an upright shaft mounted in the center of the potter's bench. The iron shaft was set in an iron cup and propelled by "kicking" a wheel attached near its base. Later improvements employed a bent shaft with a crank instead of a lower wheel. Then the potter began to work with hands and feet. A ball of moist clay, previously cut and rolled to size, was slapped on the revolving head. With moistened hands he inserted his thumbs downward into the clay and then slowly drew outward and upward until the jar attained its proper height. Meanwhile his trained fingers were working dexterously to maintain the proper and uniform wall thickness. The outside surface was smoothed with a straight stick called a "rib" or "smoother." The "rib" was held by a thumb hole in its center, and the smoothing done while the wheel was still revolving. Any rough spots which developed were touched up with a small finishing brush. To remove the jar from the wheel, which had been stopped by the foot, a thin wire attached to two wooden handles was drawn across the wheel at the base of the jar. A clean motion and the jar was free. It was now lifted to a board for transfer to the drying rack. Careful drying was important and the potter examined his "green" pots from day to day until firm enough to glaze or decorate.

GLAZING

By experience the potter knew the feel of his green ware and after several days he was ready to apply the glaze. This was usually made from red lead or from galena. In either event a thin water paste was made and run through a quern or glazing mill. Such a de-

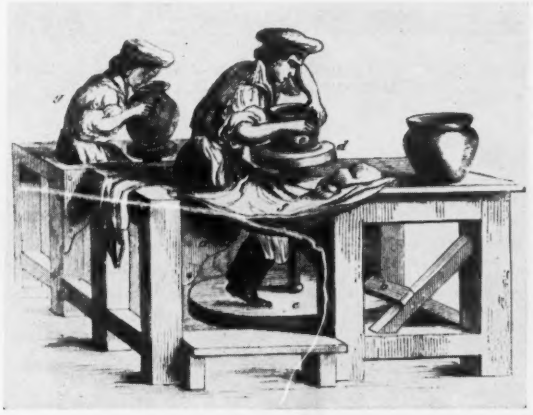


FIGURE 5.—THE POTTER'S WHEEL FROM MUSPRATT'S "CHEMISTRY"

vice is shown in Figure 6. It consisted of two stone discs with smooth grinding surfaces. In the upper stone a hole admitted the glaze mixture which was pulverized by a rotary motion of the upper stone. The mill was turned by a pole which served as a crank. The glaze ran out at the projecting rim of the lower stone.

FIGURE 6.—OLD QUERN OR GLAZING MILL. BUCKS COUNTY HISTORICAL MUSEUM, DOYLESTOWN, PA.

This mixture was applied to the inside of vessels by whirling them after pouring in a little of the liquid glaze. Outside glazes were applied when desired by dipping in the glaze paste. After firing this provided a clear, yellowish glaze—a lead silicate glass. Manganese was added to create a darker glaze, or if in excess a black enamel resulted. Verdigris furnished green tints.

ORNAMENTED WARE

There are two principal types of ornamented ware: (1) slip-decorated pottery, (2) sgraffito ware. The first refers to the application of a liquid clay or slip by trickling through a quill attached to a small cup. This method was the same as that of the ancient Romans. The term *sgraffito* (from the Italian *sgraffiare*, to scratch) means "scratched" and literally describes the method of ornamentation. It is a form of slip-engraving in which the ware is first covered with slip clay and later scratched with a pointed stick or wire.

While all types of pottery might be decorated the operation was usually applied to dishes, especially the well-known pie dishes and vegetable plates. The highly ornamented plates were never intended for daily use, but were gift plates for display.

In either case a disc of clay was first cut and rolled to size. A pie plate intended for oven baking was quickly daubed with slip tricklings from the cup, which might have one, two, or three quills to exude the white clay. When this simple decoration was dried beyond the point where it might run or smear, it was pressed and beaten into the soft clay with a wooden "batter." This prevented the slip from breaking off during subsequent use. Then the pie plate was molded to its final shape by pressing it over a heavy, baked clay mold. This was done by hand, with the convex side or bottom of the dish upward. After pressing to shape it was sponged, and then smoothed with a knife. After removing from the mold the plate was next edged with a "coggle" wheel. Subsequent drying and glazing by brush made it ready for the kiln. If the plate was a special piece, mainly for display, the molding was first done and the slip applied later.

For the sgraffito decoration the molded plate was entirely covered with white clay and designs were cut with a sharp tool. This brought out the bright red of the under clay surface. Touches of color were imparted to the designs by daubing with metallic oxides. The usual colors were yellow, green, and black.

FIRING

The old potters fired only three or four times a year. This operation came after a batch of several hundred pieces was ready for the kiln. Wood firing was the common practice and huge piles of timber were cut by the helpers in preparation for this event.

The round kiln was usually made of stone walls with an arched brick roof. An average size kiln was about nine feet in diameter and seven feet in height. The earthenware jars, bowls, etc., were nested around the walls of the kiln, but never touching each other. Row upon row was filled up, with plates and smaller objects at the top. When the kiln was filled the openings were sealed with brick and clay to prevent drafts. Then the fires were started—usually oak and hard woods being employed. Help was needed to keep the fires, because this was a long, slow process requiring from twenty-four to thirty-six hours. Two fires were started on opposite sides of the kiln. They were connected by a tunnel which led to a central chamber running through the kiln. The fires were slowly increased to heat the

kiln gradually. From sunrise to noon only a light fire was employed, then the intensity was increased until by night it was at its peak. All night long more wood was added by groups of friends who came to lend a hand. As the kiln became white-hot no smoke emerged from the crown, but only jets of livid flame which told the countryside of the progress of the firing. By morning of the second day the fires were a mass of red charcoal which would keep the kiln hot for many hours. Toward the end of the second day the potter would remove test pieces of clay which had been placed in strategic vents before the firing. The strips were about twenty inches long and protruded through the crown to the location of various pieces of ware. The lower ends of the strips dipped in lead glaze, and upon removing the strip by an attached wire the potter could see whether his work was done. When complete he inspected his kiln, chinked up any resulting cracks and then allowed the kiln to cool gradually for about a week.

The opening of the kiln was an event to draw folks from miles around. Prospective purchasers, all curious of the outcome, would crowd the scene. The potter prayed, silently at least, for success. Face, no less than fortune, was at stake. Loud was the praise if his firing was good. Then all were happy to buy the new redware—manmade utensils from handfuls of clay.

Much of the foregoing description of the methods of the potter has been obtained from the writings of Edwin Atlee Barber, former Director of the Pennsylvania Museum and School of Industrial Art. His chief contribution to the ceramic art was his demonstration of the importance of Pennsylvania German pottery. By his collections of outstanding examples of this work and his writings on the subject he became the press agent for what is almost a lost art.

POTTERY DECORATIONS

Certain types of decoration characterize the Pennsylvania "Dutch" ware. Slipware shows the waved lines, the turkey feet, and often the same simplicity typical of Indian pottery. Weygandt (*9*) mentions the Indian motives on pie plates and thinks that they "may be the very work of Indian help, which was often employed when it was available, as by the Moravians in the Forks of the Delaware." Flowers were most frequently used as the theme for decoration. The tulip and fuchsia were predominant, although often no particular flower was patterned.

Sgraffito ware repeats the portrayal of the tulip. This influence came from Germany where it was an artistic emblem ever since its introduction from Persia in the sixteenth century.

Birds and barnyard fowl were subjects of design. The peacock and the eagle were favorites. In early years the possession of a peacock was a symbol of affluence and the strutting bird was copied on pottery, tinware, samplers, and wooden chests. The pelican appears piercing her breast—another symbol of medieval times reproduced by men who preserved and copied old-world art. More original and often more crudely fashioned were contemporary subjects—soldiers, patriotic figures, horsemen, etc.

Most humorous and homely philosophical were the inscriptions which often were printed around the margins of the show plates. Barber (*10*) gives some of these to illustrate their character:

> "Wer etwas will verschwiegen haben
> Der derf es seiner Frau nicht sagen."
> (He who would have something secret
> Dare not tell it to his wife.)
>
> "Lieber will ich ledig leben
> Als der Frau die Hosen geben."
> (Rather would I single live
> Than the wife the breeches give.)

Sometimes Biblical verses were used, again amorous statements and pledges of devotion—the latter if the dish were given as a gift to a sweetheart or loved one. Often the name of the donor, or the recipient, and the date would be inscribed. Sometimes the potter signed his name or initials. Inscribed plates are always in demand especially when they establish the date and maker of the piece.

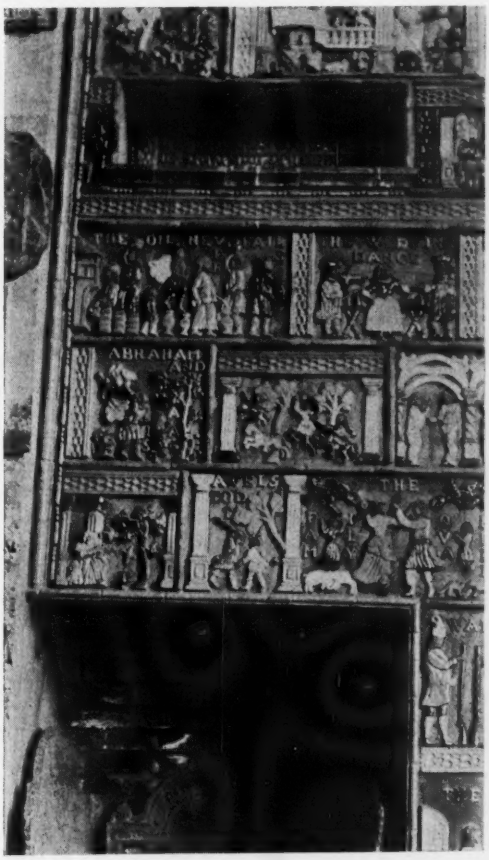


FIGURE 7.—TILES MADE BY H. C. MERCER. BUCKS COUNTY HISTORICAL MUSEUM, DOYLESTOWN, PA.

INFLUENCE

The art and craft of the Pennsylvania German potter has declined. Numerous examples of his work remain in the homes of his kinsmen, in the museums of the state and elsewhere, and, of course, in the possession of many antique collectors. This work, often crude but always colorful, represents a distinct phase in our colonial period. It passed its zenith with the introduction of pewter, tinware, and porcelain. The metal ware was stronger, the whiteware more adapted to daily use. These products in turn now give way to aluminum, glass, and plastics. Late in the nineteenth century, however, an enthusiastic archaeologist and antiquarian, Henry Chapman Mercer, became interested in the pottery and designs of the early Pennsylvania craftsman. He had collected tools and products of early industry in the United States and foreign lands. His zeal led him to invent processes for making mural decorative designs in 1899. He established a small plant at Doylestown, Pennsylvania, known as the Moravian Pottery and Tile Works. Mercer was a man of considerable wealth and he could afford to experiment and produce on a scale greater than any of the early potters. He realized the limitations of earthenware as well as its beauty, but he thought it had a distinct use in the field of architecture. He drew many of his designs from the early Pennsylvania stove plates which were famous for their pictures of Biblical stories, legends, and quaint sayings.

FIGURE 8.—THOMAS STAHL, POTTER OF POWDER VALLEY, LEHIGH COUNTY, PA.

Mercer felt strongly about the old red pottery and wrote in 1911 as follows (*11*):

> "Red, with which nature has gloriously tinted most of the clays of the world, is a wonderful color . . . . Clay moves at every slightest touch—in the sun, in the air, in the fire. . . . Let it move. Clay lives, don't kill it by pouring it like white molasses into a mould. . . . These potters painted clay with clay, they let the colors of nature alone and burnt them into the very life of the object.
>
> "Whoever wishes to study, practice, or develop pottery should overlook the modern factory and begin here. Shall it die? Thirteen years ago I said not, when I began a work which I hope will continue after me, namely an attempt to restore and develop it in the making of tiles."

Mercer's tiles have found use and acceptance in numerous buildings in floors, fireplaces, and mural decorations (Figure 7). The business was an economic success while he lived. It is still continued by successorsn amed by him. His home at Font Hill, Doylestown, and his collections in the museum of the Bucks County Historical Society are available to interested visitors.

In recent years Pennsylvania Dutch pottery and antiques have been the subject of numerous popular articles and even books. Cornelius Weygandt (*9*) has described in pleasant David Grayson style his years of study and collecting. "The Red Hills" is largely devoted to early Pennsylvania pottery. In his "The Dutch Country" (*12*) he describes the passing of the last of the old potters, but states that there may be one or two still practicing.

It has been the present writer's good fortune to learn of such a pottery in Powder Valley in Lehigh County. It is operated by the Stahl brothers, sons of an old potter who ran a pottery forty years ago in the same valley. A view of one of these old gentlemen is seen in Figure 8. Only since 1932 have they renewed a craft which they learned as boys at the hands of their father. In answer to my praise and exhortation to stick to their art, the elder (Thomas Stahl) shortly said—"Ach, but you don't mean it!" Who will be their successors in this old tradition?

EARLY CHINA IN PHILADELPHIA

This paper has stressed the redware of early Pennsylvania, but there was also an important beginning in the manufacture of china in Philadelphia in 1769. This was the work of Gousse Bonnin who came from England where he worked at the famous Bow pottery. Capital was furnished by George Anthony Morris and a factory located on Prime Street near the present navy yard. From advertisements and announcements it has been thought that the pottery early made "bone china," and later "common white" or opaque ware. Only one or two pieces of authentic Bonnin ware are preserved and they are of white earthenware, not china. The pottery failed after five years of struggling. In spite of its brief existence, Spargo regards "this early Philadel-

phia pottery as the most interesting, and also the most important, of all the potteries known to have existed in this country before the Revolution."

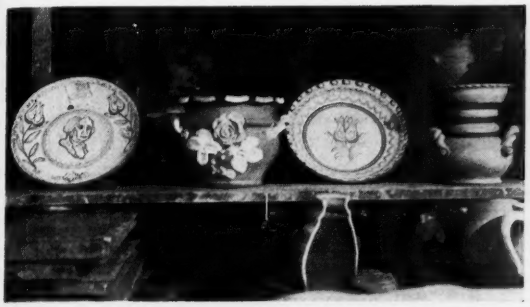


FIGURE 9.—STAHL POTTERY BEFORE FIRING

It is difficult to agree with the foregoing statement when there is so little evidence. On the other hand the German potters have left us much of their wares. Their plants were small family affairs, usually a side line to the main business of farming. Many of the potters left records through family and county histories. Names like Hübener, Haring, Singer, Headman, Diehl, and Bergey are prominent. There are dozens of others less known and many forgotten. They practiced an art which in its simplest form goes back beyond recorded history. In its highest development it comes to us in such beauteous forms as Rookwood pottery.

ACKNOWLEDGMENTS

The author wishes to acknowledge the courtesy of assistance from the following: Mr. R. G. Alleman for material concerning the Moravian pottery in Bethlehem; Miss Harriet Root of the Bethlehem Public Library, for general information; Mr. H. R. Mann for photographs from the Bucks County Historical Museum in Doylestown; Mr. Joseph Downs for permission to use a copy of the Hall of Millbach from the Pennsylvania Museum of Art in Philadelphia; Mr. H. K. Deisher of the Pennsylvania Museum in Harrisburg; and the Reverend Shultz of the Moravian Museum in Nazareth, Pa.

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Only those who worked in Bunsen's laboratory in Heidelberg, and came in daily contact with him, learned to know the great kindness of the man, and the hearty interest he took in their progress. The welfare of his pupils seemed paramount to him. He made a special point of stopping at every desk to inquire how each one was progressing. Bunsen was an expert glass blower and took pride in the fact that he could painlessly hold an almost red-hot tube in his hand without letting it drop. He was very particular that those students who came from places where chemicals and apparatus were difficult to obtain should learn how to prepare their own chemicals and make their own glassware. When he saw us use some nicely bent tube or bulb he would stop and say: "This looks as though it came from Desaga's store; please return it. You have no Desaga at home; therefore learn how to construct your own apparatus. Otherwise you may some day find yourself in dire difficulty."—ALFRED SPRINGER

At the Victoria Jubilee meeting of the British Association for the Advancement of Science, we were all gathered in the great hall when it was whispered that Mendeleeff was present. A signal was given and we called for him. After a few moments a tall, slender man with closely cropped white beard arose. When the applause subsided the somewhat embarrassed gentleman said, "I regret to say I am not Mendeleeff; I am only Lothar Meyer." The moment he gave his name he was applauded to the echo. Lothar Meyer had conceived a rival periodic theory about the same time Mendeleeff's was promulgated. He continued, "My friend, Professor Mendeleeff, cannot speak English and wishes to be excused if he expresses his thanks in the Russian language." This time an equally tall man with a mass of long brown hair and a very full-bearded face arose, looked around a moment or two, smiled, and made a few remarks in Russian, which naturally we did not understand. Both men were then heartily applauded.—ALFRED SPRINGER

CHEMISTRY *in* HIGHER EDUCATION[1]

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ON SUCH an occasion as this I need not list the ordinary and rather familiar material contributions of chemistry. The press is doing far better now than formerly in publishing the results of scientific research. The scientist is now seldom pictured as a medieval alchemist surrounded by alembics, magic paraphernalia, and dried lizards. A new scientific discovery is described rather well; but while the public learns something of its value and significance, it learns little or nothing of the process of discovery.

Nor do I need to expound the position of chemistry, along with mathematics and physics, as the foundation for other sciences and arts. The place of chemistry in many curricula bears adequate testimony to its fundamental position. This place, moreover, is not the result of educational theorizing, like much that has crept into higher school and college curricula, but comes from natural demands of the professions.

I desire, rather, to develop a role of chemistry that is different from the one just mentioned, and that I believe can bear more emphasis than it usually receives; namely, its contribution to general education. A test for this contribution would be the value that remains for one who does not make direct occupational use of what he has studied. I may illustrate this distinction between general and vocational education by two rather extreme examples. Few students of Greek can hope to become professors of Greek; there are but few professorships, and there is no other vocational outlet. However, there is no educated person who will deny the value of studying the marvelous flowering of culture that took place in ancient Greece, nor is it altogether impractical to do so. Even the business man might be better and wiser for a major in Greek in college. On the other hand, let us consider optometry, a most serviceable occupation, training for which is of value to future optometrists and their patients. Suppose, however, that the student does not eventually become an optometrist? What residuum of educational value will remain? Something of value, of course, but hardly much. Now my thesis is that the residuum may be enormous in the case of chemistry if properly taught, for chemistry is not merely a possible vocation but a science as well.

One of the most obvious services of chemistry is to develop some understanding and appreciation of our environment. The universe is made of chemical elements. The effects of their properties are visible on every hand. Even the characters of our friends are determined in part by their hormones. The great cultural periods—the Stone Age, the Bronze Age, the Iron Age, and the results today of the isolation of the light metals—are the effects of the electrochemical series of elements. The migrations, wars, and trade arteries of history have been in part determined by the occurrence of the elements and compounds. The historian himself is not always equipped to see these things, but they are there and their appreciation contributes to education.

Equally important, though less appreciated, is the tremendous impact of scientific thinking on human civilization. Some notion of this may be obtained by considering the essence of Greek tragedy, which is, perhaps, the noble but hopeless struggle of man against purely arbitrary divine enmity. Today we are still often defeated, but we believe that something could and should be done about our calamities. Lord Dunsany has vividly pictured this emancipation in one of his imaginative tales, "The Men of Yarnith." The inhabitants of this fabulous country were sorely stricken by drought and famine, but believing these calamities to be sent, or at least permitted, by their god, Yarni Zai, they did little about them but "pray to Yarni Zai as he sat far off beyond the valley, praying to him night and day to call his Famine back, but the Famine sat and purred and slew all the cattle and dared at last to take men for his food." But one bold man, Hothrun Dath, sought out the god in his remote mountain valley, to make a special plea. He found the great stone image with "the marks of instruments of carving about the figure's feet." Enlightened, he reported this to his fellows. "Then the men of Yarnith, when they knew that the Famine came not from the gods, arose and strove against him. They dug deep for wells, and slew goats for food high up on Yarnith's Mountains and went afar and gathered blades of grass, where yet it grew, that their cattle might live. Thus they fought the Famine, for they said: 'If Yarni Zai be not a god, then is there nothing mightier in Yarnith than men, and who is the Famine that he should bare his teeth against the lords of Yarnith.'"

The emergence of this same struggle of the scientific method and spirit against entrenched and arbitrary authority is likewise vividly portrayed by Merejkowsky in his "Romance of Leonardo da Vinci," a rare fusion of literary skill with appreciation of the essence of science.

The contrast between the different approaches to problems may be illustrated from my own experience with the minds of freshmen. I shall not apologize

[1] Address delivered at the dedication of the new Chemistry Laboratory at Oregon State College, Corvallis, Oregon, December 2, 1939.

for this little excursion into psychology, for the professional psychologists have largely abandoned the study of freshmen for that of rats. We cannot wait for them to fathom the minds of rats and then work up again—we may charitably assume that it is up—to freshmen, for the freshmen are with us in the meantime and we have to do what we can for them.

I tell them that I have observed four ways commonly used for solving problems, whether by freshmen or by others. The first may be called "the formula method." You get a formula from the book or from a teacher, write it on your cuff or commit it to memory long enough to pass the examination, feed in the numbers like meat into a sausage machine, turn the crank, and get out the results. The operator may not understand the machine at all; it was designed and constructed by others. This process plays a large role in education, even in courses in chemistry, physics, and mathematics, where it is essentially out of place. For example, the high-school student is taught that a formula can be derived from a percentage analysis by dividing percentages by atomic weights, and so forth. Why, he usually cannot explain. He even converts actual weights obtained by analysis into percentages before proceeding, for that is what the formula seems to require.

Another trouble with dependence on formulas is that we cannot equip the student with formulas for even a fraction of the problems that life presents; and even if we could, he would not remember them all and many of them would be wrong. The final average is low for this method of meeting difficulties.

Next comes the method that we may call "the flash-of-inspiration method." You read over the examination questions and then cast your eyes upward and pray for light. The trouble with this is that few people can get inspiration when it is wanted, and some never get it at all. The returns by this method are still lower than by the previous one.

Third comes what may be called "the dice-throwing method." You throw the numbers onto the paper, and if you have luck they arrange themselves so as to give the right answer. For example, you write $A:B::C:X$ or perhaps it is $X:C$. You then try to recall the rule about means and extremes. If you have good luck, X and C are arranged in the right order and, if you can remember the rule, you get the right answer. The trouble is here that there are so many wrong arrangements possible. You are in the position of the man who called up Information over the telephone and said, in a distressed tone of voice, "Please tell me what wrong number I must call in order to get Prospect 4321."

The fourth method is the method of analysis. One takes stock of data given. One must first eliminate non-essentials. For example, if you want to know how much soda is necessary for Mrs. X to make some round buns on Sunday morning, December 3, at 8:00 A.M., when the moon is in the last quarter and President Roosevelt is in the White House—whether in his last quarter or not, we do not know—it is obvious to an intelligent person that most of these attendant circumstances are not pertinent to the essence of the problem. As soon as the problem is divested of all such adventitious information, a person with a reasonably well-trained mind looks at the goal, just as a person endeavoring to get across the stream looks at the opposite bank; if he cannot make it at one jump, he then hunts for a series of stepping stones, each one of which he can make in a single step. In analytical thinking, a series of similar steps is discovered, so that a person may go from the data given to a desired conclusion in an orderly and logical way, without getting his intellectual feet wet.

Finally, since errors may creep in, either into the premises or into the logic, the results may be tested where possible or necessary by experiment. Now chemistry lends itself excellently to this process. For example, while it is possible in qualitative analysis merely to call for a recipe for treating an unknown (which represents the formula method), it is possible to use the type of question which we have developed, in which we give a list of possible solid constituents of an unknown, followed by partial observations of its behavior. We ask the student then to draw conclusions concerning the presence or absence of each of these constituents. This involves not only knowing the reactions but being able to gage the effects of cross-references, as in a game of chess. A correct answer is evidence not only of chemical analysis but of intellectual analysis.

A most valuable feature of chemistry is its emphasis on the authority of experiment. The test tube, not the teacher or the book, is final. The most valuable educational experience I ever had was in high school. The teacher of chemistry was the principal, who had had one year of college chemistry. I had learned by myself more chemistry than he knew, and instead of imposing the authority of his position upon me, he gave me the key to the laboratory and turned me loose. There were plenty of real problems in my head. I had a book entitled "Chemical Philosophy," by a Harvard professor, in which the elements were rigidly divided into "artiads" and "perissads," those of odd and even valence. Now this rigid division worked well for most elements, but to make it apply universally, the professor liked to double up his formula by the aid of assumed extra bonds. Nitrogen in ammonia, nitrous oxide, the trioxide, tetroxide, and pentoxide could be assigned odd valences in each case. The chief flaw in the system was furnished by nitric oxide, NO. The professor claimed that two molecules of this substance are hitched together by a third bond. I therefore undertook to find out by the aid of high-school facilities whether it really was N_2O_2 or just simple NO. I collected this gas over water in a eudiometer tube and oxygen in another tube. I poured the nitric oxide into the oxygen, so that the latter would be in excess and there would be no possibility of forming the trioxide. The tetroxide formed dissolved in the water, and the volume relations in the chemical reaction which took place enabled

me to show by the aid of Avogadro's Rule that the formula was NO.

Now, I'm sure that for this high-school student it did a great deal of good to find out conclusively that a Harvard professor could be wrong. It was probably the most important single research he has ever done.

I insist that it is a fine thing for a student to have the privilege of proving the book or the teacher to be wrong. The courses in so-called "social science" overwhelming many high schools today do not permit this so clearly. The practice of scientific method in chemistry provides a wholesome antidote to shoddy thinking in the social sciences.

Another advantage of chemistry is that it is hard. It does not lend itself at all well to over simplification. We are continually beset in this world by patent-medicine vendors, who offer simple panaceas for complex social ills. The platforms of political parties abound in them. We are told, for example, that prosperity would result if government would only leave business alone. That sounds delightfully simple, but people who fall for it overlook the fact that a depression developed when business was being pretty much let alone, and big business itself immediately began calling for help. Of course it does not follow that present government policies are wise. In California, we are very active in brewing such remedies, and the more extravagant the claims, the more appeal they seem to have. If a medicine is advertised to cure everything from dandruff to corns, by golly, it must be pretty good. The economics of Ham and Eggs is most appealing, for it offers to get prosperity out of a hat. It is in chemistry that we learn most forcibly that equations must balance.

It is important to recognize what cannot be done or known. I was lecturing one day on the arrangement of observations on chemical reactions, so as to draw conclusions regarding others. After a rather complicated series of comparisons, I came to the conclusion that a certain reaction could not be predicted at all. A certain student emitted a noise which indicated that he thought we had been wasting our time. This gave me an opportunity to point out how important it is to know sometimes that certain statements such as people make cannot be based on any sort of real knowledge. It would be very fine, of course, to be able to predict the stock market; but that is not an argument in favor of giving courses in predicting the stock market. Indeed, it may save one a great deal of expense if he can recognize the fact that solicitors for contributions and investments usually cannot possibly know the things that they allege.

Chemistry is a real discipline. Chemistry cannot be handled by mere memory; it has to be understood. It cannot run wild among a forest of verbiage; it is checked by a stern nature herself.

Chemistry shares both the more deductive, rigid approach characteristic of physics with the more inductive approach characteristic of biology. We can be rigid and quantitative in part, but we also possess a vast array of material not yet subject to rigid treatment, concerning which we have to be content with predicting correctly, say, four times out of five. The subject is therefore capable of exemplifying various aspects of the scientific method.

Chemistry has the advantage of offering the student, almost from the start, the opportunity to practice scientific methods. An "unknown" in qualitative analysis is a little research. It has all the appeal of cross-word puzzles or games of skill. The overemphasis on so-called student "activities" in our institutions is evidence that we leave too little scope for initiative in their academic work, which, I suppose, should be called "student inactivities." I find that the students of chemistry in my own institution are excited about it to a degree seldom found in other groups. They argue with each other, they pump me for information about the whole universe, even in my freshman quiz sections. Let us keep this up; other academic work needs this atmosphere.

Indeed, society needs the corrective service of science. Nature equips us, for both enjoyment and protection, with emotions as well as intellect, but these are too rarely harnessed together. Even in this age of science, few important questions are determined by scientific methods, even where it offers the only hope. The terrible inhumanity rife in Europe and Asia today is not the product of science, but of mass paranoia, which has prostituted some of the results of science to its own fevered dreams. The violent tirades of persons in this country possessed of Messianic complexes offer mirages only; they do not guide along the slower, more painful paths of true progress and happiness. What hope do we have, except that men may be taught, patiently and slowly, to distrust violent methods, and to discipline themselves to honest thinking, with emotion motivating but not dominating reason? Emotions are fine for binding together family and friends, for enjoying art and nature, for giving courage and loyalty, but even in these realms, emotions cannot run amuck without danger, and in the complex problems involved in the relations between masses of men, we must be intelligent if we possibly can. Humanity spends so much time recovering from quick remedies, that it would be better to cease taking these, even though no specific can be offered in their places.

In order to make our chemistry serve the ends of liberal, as well as vocational and professional education, we must endeavor to teach it as science, not as dogma. We must be critical of time-worn explanations, venerable from repetition, unsupported by either logic or evidence, such as the statement that in the electrolysis of a sodium sulfate solution the sodium first deposits, then reacts with water. If the electrons finally get to the hydrogen ions of water, why cannot they go there in the first place? No one says that in an electrolysis of a solution containing copper ions and zinc ions, the zinc first deposits and then replaces the copper. Why should one offer a corresponding explanation in the other case?

I knew a professor who defined chemistry as "the science dealing with the deep-seated permanent changes in matter." The definition was illustrated by picking up a piece of iron with an electromagnet and then turning off the current so that the iron was dropped. This was a temporary change, and therefore "physics, not chemistry." I used to want to ask what would be the result if the core of the magnet had been steel instead of iron, when the magnetism would have been permanent. Would that make it chemistry? But such questions were not in order.

Good teaching must, it seems to me, be vitalized by research. A good research man is not necessarily a stimulating teacher, but can a teacher, even though entertaining, be truly great if he has not enough curiosity about his subject to ask a few hitherto unanswered questions? Science is to be found in books, yes, in part, but it is not a stagnant pool from which men dip medicinal draughts; it is a living stream, with sources high among the snows, unattainable by the many, but a stream that nevertheless flows down among the habitations of men and waters their homes and fields.

EXTRACTION *of* RADIUM *from* CANADIAN PITCHBLENDE[1]

ALICE KUEBEL

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THIS paper consists essentially of two parts: first, a description of the commercial process for the utilization of Canadian pitchblende; and second, a brief outline of some of the work we have done in the laboratory of the Erie Center of the University of Pittsburgh in reproducing the commercial extraction of radium on a small laboratory scale.

The largest known deposit of pitchblende in Canada is found in the Great Bear Lake district of the Northwest Territories. Ore is hand-selected at the mines—the richest pitchblende being characterized by a thick, black, botryoidal formation. It is crushed and then concentrated by a gravity-water classification process in which the heaviest ore, also the richest, is separated from the lighter ores and metals. The concentrate is sent by boat and rail to the radium refinery at Port Hope, Ontario. Because approximately seven tons of chemicals are needed to treat a single ton of concentrate, the refinery is located closer to the supply of chemicals than to the source of the ore.

The composition of the ore varies with different veins found at the mine; each batch of concentrate must be analyzed before it is sent through the refinery to ascertain the exact amounts of chemicals which will be necessary at each step in the treatment of the individual batch. Details of operation are changing constantly, and the procedure followed is not precisely the same from month to month. Besides radium, the concentrate always contains appreciable, but varying, quantities of uranium and silver. The extraction process, to be economically feasible, must include a separation for these two elements. Dr. Marcel Pochon, who studied under the Curies, adapted their process for the extraction of radium to the special requirements for the commercial utilization of Canadian pitchblende.

The first operation at the Port Hope refinery is a thorough roasting of the ore in a tall Herreshoff furnace to decompose carbonates and sulfides. Carbonates and sulfides are removed to prevent excessive frothing in the sulfuric acid leach which is the first of the wet treatments. Two tons of bagged concentrate are fed each day into the top of the Herreshoff furnace at 900°F.; then they fall slowly downward over approximately twelve revolving grates to the bottom of the furnace where the temperature sometimes reaches 1400°F. Oil is used for fuel. The product of the

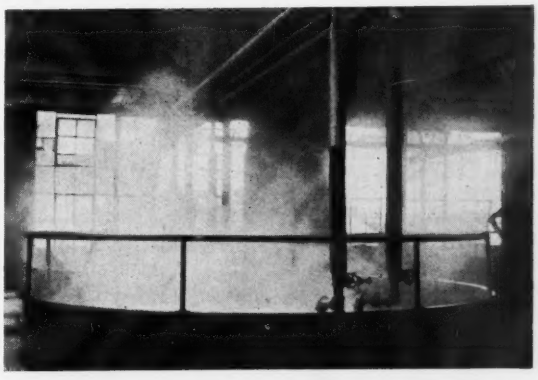
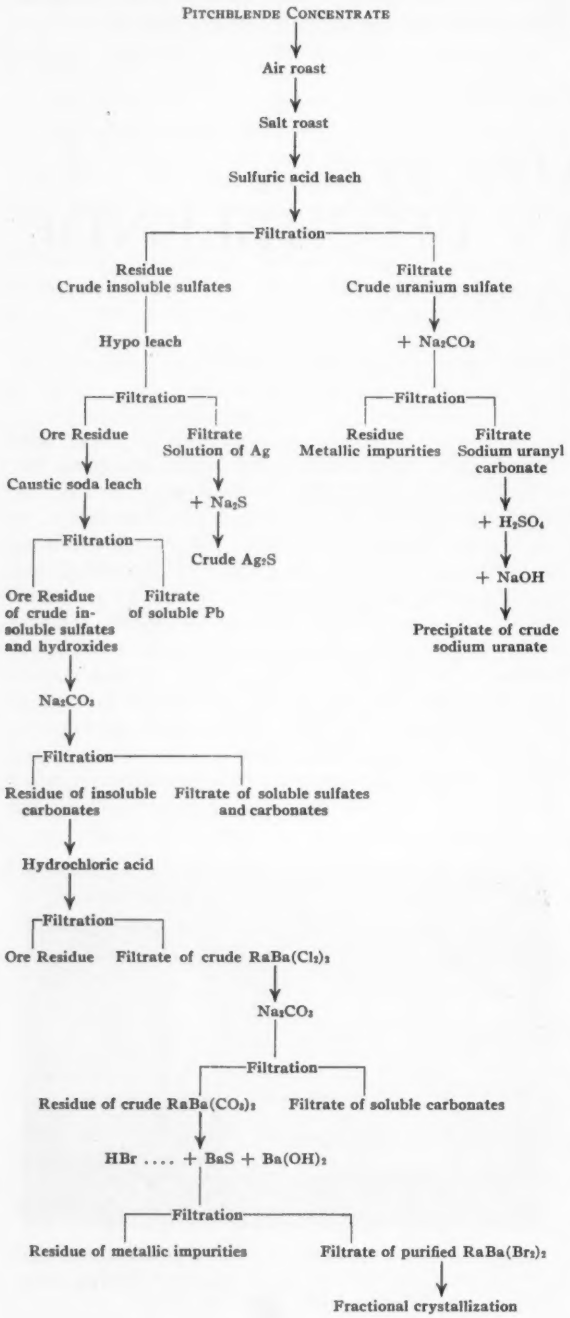


FIGURE 1.—A VAT IN THE URANIUM REFINERY BUILDING. CRUDE URANIUM SULFATE IS STEAM-BOILED WITH Na_2CO_3 TO PRECIPITATE METALLIC IMPURITIES

[1] Presented before the student meeting of the Division of Chemical Education at the ninety-ninth meeting of the A. C. S., Cincinnati, Ohio, April 10, 1940.

Herreshoff furnace is reroasted with common salt to convert silver to silver chloride. In the form of the chloride, silver may be completely extracted from the ore with sodium thiosulfate. Two salt roast furnaces, also using oil as fuel, are used, but extremely high temperatures must be avoided to prevent loss of silver chloride by volatilization.

After the two preliminary roasts have been completed, the ore is sent through a series of wet treatments. The first of these is a sulfuric acid leach which extracts uranium as crude uranium sulfate. Approximately four hundred pounds of ore are placed in each of six tanks with a 1:1 solution of commercial concentrated sulfuric acid; *i. e.*, a solution which is 50 per cent by weight of concentrated acid. The leach takes six hours, and during this time a small amount of hydrated barium chloride is added. Barium must be added in some form to act as a carrier for the precipitation of the minute quantities of radium. The chemical properties of barium and radium are almost identical, and a radium salt is readily co-precipitated by the corresponding barium salt so that radium sulfate and barium sulfate precipitate together. More sodium chloride is also added here to precipitate any silver which might have escaped the salt roast and might still be in the form of a water-soluble compound. Sodium nitrate used to be added for the purpose of oxidizing the uranium, but it is no longer considered to be a necessary step. This sulfate mixture is filtered by suction through canvas. The filtrate of bright green uranium sulfate is made as nearly neutral as possible to minimize corrosion, and then is piped to the uranium refinery. From the crude uranium sulfate, a variety of compounds are prepared; these include the nitrate, the acetate, and the oxide, which are used chiefly in photography and in ceramics.



The ore residue from the sulfate filtration contains the insoluble radium-barium sulfate and silver chloride, but also contains many impurities such as lead, calcium, silica, etc. The residue is taken from the filter bins in small hand carts to the acid-resistant Haveg tanks for the second step in the wet process. This consists of the extraction of silver chloride with sodium thiosulfate. Sodium thiosulfate is added in proportion to the amount of silver the ore is known to contain. The leach is filtered, and the filtrate which contains the silver is treated with sodium sulfide to precipitate silver sulfide. Crude silver sulfide is sold to silver refineries in the United States. Although it used to average around 1500 ounces per ton, the ore now being used is much poorer in silver, and it now averages only from 400 to 1000 ounces per ton.

The residue from the hypo leach, which contains radium-barium sulfate, also contains enough lead sulfate to necessitate a separate step for its extraction. The lead is dissolved by boiling with a 15 per cent solution of sodium hydroxide for from one to two hours. The mixture is filtered, and the residue which still contains the radium-barium sulfate is washed thoroughly. The filtrate is discarded. The wet ore is next boiled for four hours with one and one-half times its weight in sodium carbonate to convert the radium-barium sulfate to the carbonate. From this point on, all steps are for the purification of the radium-barium compound, and finally for a separation of the radium salt from its barium partner. The carbonates are filtered, and the insoluble radium-barium carbonate residue is decomposed with hydrochloric acid to form a solution of crude radium-barium chloride. Now, for the first

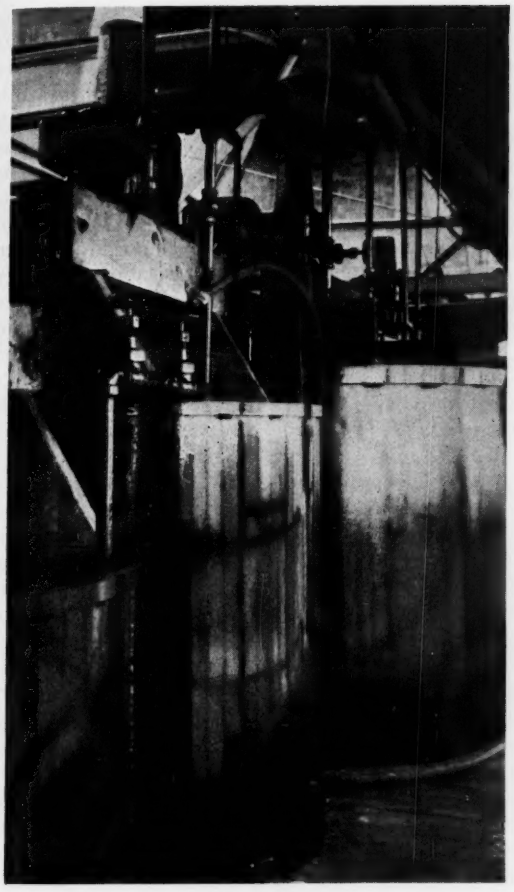


FIGURE 2.—TANKS USED IN THE EXTRACTION OF RADIUM FROM THE ORE RESIDUE WHICH IS LEFT AFTER REMOVAL OF URANIUM AND SILVER

time, the radium is kept in solution. That is, up to this stage, impurities have been dissolved away from the radium, and now radium is dissolved away from most of the remaining impurities. The succeeding steps in the purification of the crude radium-barium chloride in the refinery building involve a double precipitation as the carbonate, redissolving the carbonates in hydrochloric acid, and again a final precipitation as the carbonate. The insoluble residue of radium-barium carbonate is the product which is now transferred from the refinery to the laboratory.

The carbonates are boiled with hydrobromic acid in open granite basins over coal-gas burners. The mixed bromides are purified further by additions of barium hydroxide and barium sulfide, which precipitate the last traces of accompanying impurities, chiefly iron and lead.

Finally, the radium is separated from the barium (though not completely) by a long and systematic series of fractional crystallizations of the mixed bromides. Saturated radium-barium bromide liquor is put into large quartz evaporating dishes in a cooling room just off the main laboratory. Because radium bromide is slightly less soluble than barium bromide, the first crystals contain more radium and less barium than the mother liquor. If these first crystals are separated from the liquor and are redissolved, the resulting solution, when saturated, will yield crystals which contain a higher percentage of radium than the first crop. The large quartz dishes (which, though expensive, are preferable to glass because of greater durability and purity) are arranged systematically on tables in the cooling room. The first crystals of mixed radium and barium bromides contain, very roughly, 500,000 parts of barium to one of radium. The final crystals contain approximately one part of barium to nine of radium; and these last crystals are sealed, 100 milligrams at a time, into glass tubes each valued at $3000. The tubes are stored separately in lead cylinders which fit into shelves inside a lead safe. Radon emanation is not removed from the tubes, but stagnant air above the safe is occasionally drawn out by suction pumps and bottled. Radium used in hospitals, or on the dials of watches and airplane instruments, or in the detection of internal flaws in metal parts, is not radium alone, but it is this radium-barium bromide combination containing enough selected impurities to produce a pronounced glow. The glow which is characteristic of a radium compound is caused mainly by the agitation of impurities present in the compound rather than by alpha, beta, and gamma rays alone.

Throughout the entire process at Port Hope, an electroscope is used to detect valuable amounts of radium which might otherwise be discarded with worthless residues or solutions. At the present time, a research division is working on the residue which remains after the second radium-barium carbonate is treated with hydrochloric acid. Heretofore, the residue had been dumped along the sides of an inlet of Lake Ontario.

In laboratory work at the Erie Center, University of Pittsburgh, we have separated the uranium, the silver, and a very small amount of radium as mixed radium-barium bromide from 1050 grams of Canadian pitchblende. In essential details, we followed the process

FIGURE 3.—LARGE QUARTZ EVAPORATING DISHES IN THE COOLING ROOM. THE DISHES COST $9.25 APIECE, BUT ARE PREFERABLE TO GLASS BECAUSE OF GREATER DURABILITY AND PURITY

FIGURE 4.—LEAD SAFE (LOWER RIGHT) IN WHICH GLASS TUBES, CONTAINING 100 MG. OF $RaBa(Br_2)_2$ EACH, ARE KEPT IN INDIVIDUAL LEAD CYLINDERS

described by Dr. Pochon as in use at the Port Hope refinery.[2] Considerable guessing had to be done with reference to quantities of chemicals we should use at each step throughout the process because we had no way of knowing the exact composition of our ore. There were three batches altogether: 100 grams, 500 grams, and 450 grams. The first batch consisting of 100 grams will be described here (partly, at least) because it was the most successful.

The preliminary roast and the salt roast were carried out in a large evaporating dish over a Bunsen burner. The ore was kept at a cherry-red for approximately one-half hour, and then was allowed to cool before being weighed and reroasted for two and a half hours with 7.5 grams of salt. Loss in weight during the first roast amounted to 3.7 grams, but during the salt roast the ore gained two grams in addition to the weight of the salt. This increase in weight with the salt roast also occurred with the two later batches; the gain may possibly be explained by oxidation. The resulting 105.8 grams were transferred to a beaker and treated with a solution of 60 grams of concentrated sulfuric acid in 60 grams of water. This mixture, greenish brown in color, frothed considerably; the evolution of chlorine and hydrogen chloride gases were noted by their odors. Approximately one gram of barium chloride was added producing a chalky white precipitate of barium sulfate; and later five grams of sodium nitrate were stirred into the mixture with no noticeable reaction except a slight evolution of nitrogen dioxide. Upon settling, the supernatant liquid of crude uranium sulfate was a clear dark green; and the ore at the bottom of the beaker was gray and muddy. We filtered this by suction through filter paper in a Büchner funnel. The filtrate of crude uranium sulfate was put aside; the residue in the funnel was washed thoroughly to free it from soluble chlorides and sulfates. For the extraction of silver, we added 7.5 grams of sodium thiosulfate in approximately 25 cc. of water to the ore residue. After settling overnight, the hypo leach was suction-filtered and washed. Silver was precipitated from the filtrate with sodium sulfide; and silver sulfide was separated from the solution by filtration in an ordinary funnel. Our yield of the dry sulfide amounted to 4.5 grams, of which 3.9 grams (87.06 per cent) were silver. The ore residue (46.5 grams) after filtration of the hypo leach was boiled for one and one-half hours with 200 cc. of a 10 per cent solution of sodium hydroxide. The hydroxide leach was suction-filtered; the filtrate containing lead and silica was put aside, and the residue of insoluble sulfates was dried in an oven at approximately 105°C. The dried residue containing crude radium-barium sulfate weighed 40.0 grams. To it were added 60 grams of sodium carbonate in 275 cc. of water, and this mixture was boiled for six hours under a reflux

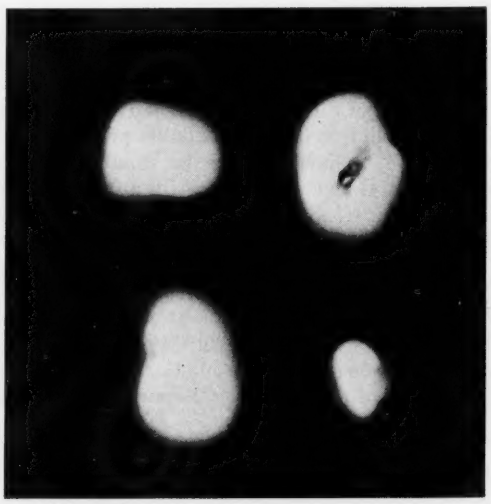


FIGURE 5.—CONTRAST PLATE EXPOSED EIGHT DAYS TO CANADIAN "BOTRYOIDAL" PITCHBLENDE

[2] POCHON, "Radium recovery from ores," *Transactions of the American Institute of Chemical Engineers*, Vol. **33**, No. 2 (1937).

condenser to convert the radium-barium sulfate to carbonates. After filtration and washing, the insoluble material (containing radium and barium as carbonates) was transferred from the funnel to an evaporating dish, and partially decomposed there with dilute hydrochloric acid. We filtered this mixture through an ordinary funnel; the residue of approximately 25 grams now contained only waste materials; the filtrate contained crude radium and barium chlorides. The radium and barium present in the filtrate were reprecipitated with sodium carbonate, then filtered and washed in a small Büchner suction funnel. The impure radium-barium carbonates weighed, when dry, 11.10 grams; these were decomposed in hydrobromic acid to produce a solution of radium-barium bromide. The bromide is used in fractional crystallization because of the more advantageous enrichment factor for radium bromide as against radium chloride. Metallic impurities were precipitated from the solution with barium hydroxide and barium sulfide, and separated by filtration. A series of crystallizations was carried out with the purified bromide solution in glass beakers.

Our final crystals do contain some radium; they take about one day to fog a photographic plate, whereas a chunk of pitchblende requires about six days to affect the plate to the same extent. In comparison, a 100-milligram tube at the refinery took less than two minutes to make an impression on a relatively slow lantern slide plate, and a heavier impression on a contrast plate which lay directly under the first. The crystals from the 100- and 500-gram batches contained the most radium. The exact concentration of radium in the crystals from the 500-gram batch amounted to 4.38 micrograms. This was determined by comparing the gamma ray emission from the crystals with the gamma ray emission of a known sample of a radium salt. The comparison was made with a Geiger counter in the University's physics laboratory in Pittsburgh through the courtesy of Dr. Simmons and Dr. Allen, which I should like to acknowledge. I should also like to express my appreciation to Dr. L. A. Goldblatt, who suggested the problem to me, for his coöperation and advice.

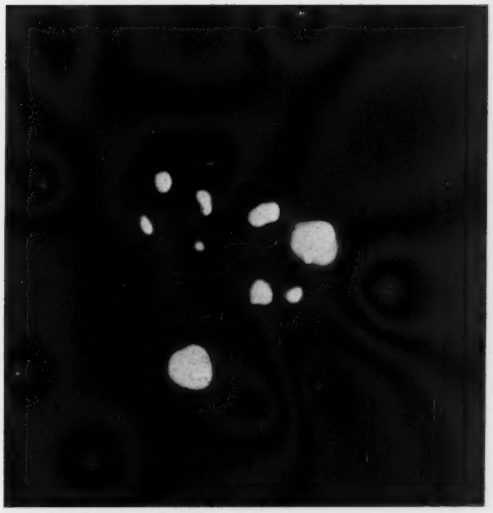


FIGURE 7.—$RaBa(Br_2)_2$ CRYSTALS FROM THE 100-GRAM BATCH. CONTRAST PLATE. TWO DAYS

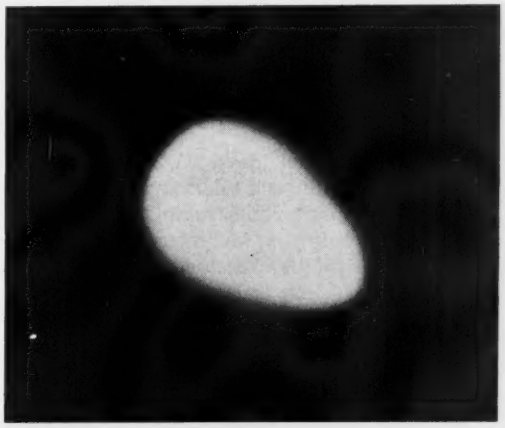


FIGURE 8.—THE 100-MG. TUBE WAS EXPOSED TO THIS SINGLE CONTRAST PLATE FOR APPROXIMATELY TWO MINUTES

FIGURE 6.—CONTRAST PLATE EXPOSED EIGHT DAYS TO BELGIAN PITCHBLENDE

Editor's Note: We have inquired about sources of uranium ore for work similar to that described in this paper and find that the price of Canadian pitchblende is prohibitive ($12.75 per pound), due principally to export restrictions. Possible American sources of uranium ore are:

United States Vanadium Corp., Uravan, Colo.
Shattuck Chemical Co., 1805 S. Bannock St., Denver, Colo.
Gateways Alloys, Inc. (Geo. W. Brown, President), Palisade, Colo.
George Snyder, Frank Snyder, or C. A. Snyder, Egnar, Colo.
Mesa Vanadium Co., Grand Junction, Colo.

IDEOLOGICAL UNCERTAINTIES *in* TITRIMETRY

M. G. MELLON

Purdue University, Lafayette, Indiana

AMONG the analyst's wide variety of methods of measurement, titrimetry has attained an almost dominant position, at least in industrial practice, in the century and a third since the proposal of the first procedure by Descroizilles (*1*) in 1806.[1] This may be attributed to certain unique advantages of titrimetric technic and to the range of applicability of the method.

One might reasonably expect that more than a century of general use would have brought definiteness and consistency in, and adequate justification for, the concepts and terms employed. An inspection of recent analytical publications and of examinations submitted by graduate students from nearly every state in the Union has convinced the author, however, that certain aspects of the subject are still confused in the minds of many.

For this state of uncertainty writers must take the most blame, as they are the principal originators and transmitters of recorded ideas. Administrators come next in line for selecting and tolerating uninformed, uncritical, and mentally lazy instructors. Teachers who have little knowledge of, or interest in, analytical chemistry can hardly be expected to make much contribution to the subject, or even to be accurate interpreters and transmitters of the work of others. Finally, there are the non-skeptical students who accept everything on authority.

The purpose of this article is to direct attention once more to certain ideas or concepts on which agreement in usage seems both feasible and desirable. If the chemists concerned will coöperate, most of the present confusion and uncertainty need not persist.

Definitions

In the establishment of standards for the metric system an error in measurement resulted in our now having two units of volume. The first, the cubic meter, is related to, or derived from, the standard meter bar. One cubic centimeter is $^1/_{1,000,000}$ of the cubic meter. The second, the liter,[2] is related to the standard of mass, the kilogram, in being defined as the volume occupied by a kilogram of "pure" water[3] at the temperature of its maximum density and under a pressure of one atmosphere. Obviously, $^1/_{1000}$ of a liter is a milliliter and *not* a cubic centimeter. Although analytical work could be done in terms of cubic decimeters and cubic centimeters, the National Bureau of Standards has specified the use of liter and milliliter, and manufacturers of the best American apparatus mark their products in these units. It seems unfortunate, therefore, for any individual writer, or committees editing official methods, to use the term liter and then designate the $^1/_{1000}$ subdivision as a cubic centimeter.

Such carelessness or inconsistency is often defended on the ground that it makes no practical difference since cubic centimeter and milliliter differ by only 27 parts per million. Even this amount, however, would be an intolerable error in weighing 100 g. of solution to four decimal places, as in precise density determinations.[4] In addition, disregard of such items is scientifically unsound.

Another definition still often inadequately specified is that for equivalent weight (*2*). The statement should indicate that the values, as ordinarily used, refer to the naturally occurring isotopic mixtures of hydrogen or oxygen. Furthermore, the significant figures given should be adequate for analytical work, as 1.0080 for hydrogen and 8.000 for oxygen.

A third point concerns standard solutions. Perhaps everyone agrees that such a solution is one of known value, and that this value may be expressed in terms of the concentration of the solute, or of some constituent with which the solute will react, or to which it is chemically equivalent. What is often forgotten, or unrealized, is that the concentration may be expressed either on a volume or mass basis, the former being applicable to volume burets and the latter to weight burets. When the volume basis is used, usually one employs the normal or molar system, or expresses the concentration in terms of grams per milliliter. For the mass basis the molal system is a recognized favorite among physical chemists, but analysts prefer simply grams of solute per gram of solution.[5]

Terminology

Many years ago Winkler (*6*) recognized the merits of

[1] Information supplied by Professor W. T. Hall.

[2] The liter is often designated as a unit of capacity. See BRIGGS, *Rev. Modern Phys.*, **11**, 111 (1939).

[3] This is water consisting of the naturally occurring isotopic mixtures of hydrogen and oxygen.

[4] If such densities are to carry six or seven significant figures, one must designate whether the unit is g./cm.[3] or g./ml.

[5] The percentage system, correctly applied, is sufficiently definite but not very useful.

the word titrimetric[6] to designate measurements based upon determining the amount of a standard solution chemically equivalent to the desired constituent. More recently, Washburn (*5*) especially recommended its use. It should be obvious that the more common term, volumetric, is entirely inappropriate for titrations using weight burets, since there is then nothing involving volume in the measurement.

A second reason for using the word titrimetric is to reserve the word volumetric for those measurements in which the property measured is the volume of the desired constituent, or something related directly to it (*3*). This then provides for a logical grouping of methods involving determinations of matter in any of its three physical states. Examples of such procedures are (*4*): gases—oxygen in the air, by change in volume; liquids—water in petroleum products; and solids—phosphorus in steel, by centrifugation of the ammonium molybdiphosphate precipitate.

In this class of measurements other terms are used which need reconsideration. For classifying the methods of titrimetry it is convenient to subdivide them, first of all, according to the type of chemical reaction involved in the titration. We then have such classes as neutralimetry, redoximetry, precipitimetry, and compleximetry. Divisions of these classes may be designated by the kind of reagent used. Thus in neutralimetry we have acidimetry and alkalimetry (or possibly basimetry),[7] and in redoximetry we have oxidimetry and reductimetry. These divisions may be subdivided according to the names of the specific reagents used in the titrations. Examples of these, for which the usage is generally accepted, are permanganimetry, iodimetry (iodine used as an oxidant), cerimetry, argentimetry, and mercurimetry. Logic and consistency suggest the extension of this scheme, if analysts have any interest in systematic classification.[8]

Also in titrimetry, as in other kinds of analytical measurements, analysts have the problem of using consistent and acceptable terms for the more general aspects of the subject. Thus, the term basic would seem to require the term acidic as its opposite, instead of simply acid, as used by many writers. Inspection of the titles abstracted by *Chemical Abstracts* shows much lack of conformity to approved editorial practice. For indicating valence states the prefixes uni-, bi-, ter-, quadri-, quinque-, sexa-, septa-, octa-, etc., should be used. Names of inorganic compounds, particularly the complexes, often are not based on accepted principles of nomenclature. For example, ammonium molybdiphosphate applies to the formula $(NH_4)_3[P(Mo_3O_{10})_4]$, and potassium hexacyanoferriate to $K_3Fe(CN)_6$.

The Basis and Method of Calculating Results

The normal basis of specifying concentration of standard solutions, attributed to J. J. Griffin, has had a particular appeal to chemical writers and instructors. In fact, teachers have indoctrinated their students so thoroughly with the normality tradition that the author has had hundreds of juniors who seemed unable to calculate a titrimetric determination without involving, in some way, the normality of the titrant.[9] Some think that even the unknown solution, of unknown volume and value, must be considered somehow to have a normality.

The normality concept is not without value; but unbiased teachers should not neglect to mention its defects. Since present teaching seems to overemphasize the merits, this discussion is limited to the uncertainties and to the hindrance attendant, in many cases, upon its use.

Ideally, any system of designating the value of a titrant should provide a specification having no uncertainty, a requirement which the normal system often cannot meet. Several examples will illustrate the difficulties. In neutralimetry orthophosphoric acid may be cited. A recent book, favorably reviewed, states that the equivalent weight of this compound is one-third of the molecular weight. This conclusion would have practical justification only if all three hydrogens were titratable. Standard reference works state that one hydrogen reacts with a base, using methyl orange as the indicator, and two using phenolphthalein. In the former case the equivalent weight is the molecular weight, while in the latter it is one-half the molecular weight. Because of the small ionization constant, there is no precise method for titrating the third hydrogen. Therefore, to state that a solution is normal with respect to orthophosphoric acid is an insufficient specification of concentration. In redoximetry potassium permanganate is another well-known example. Depending upon the way it reacts, its equivalent weight is one-third, one-fourth, or one-fifth of the molecular weight.

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[6] Somewhat earlier Mohr used the equivalent of titration methods, as in the fifth edition of his "Lehrbuch der Chemisch-Analytischen Titriermethoden," **1877**.

[7] It should be noted that the use of the terms acidimetry and alkalimetry is the opposite of that in practically all current analytical writing. The change is necessary, however, to be consistent with other accepted usage.

[8] The apathy of chemists for classification of analytical methods is a curious phenomenon. One has cause for thought when writers convey the idea that methods of analysis can be adequately classified as gravimetric, volumetric, and special processes, with the amazing limitation that the gravimetric group includes only those employing precipitation as a means of separation. What would we think of a book on organic chemistry in which the classes of compounds were hydrocarbons, alcohols, acids, and special groups, or of a book on inorganic chemistry in which the classes discussed were alkali metals, halogens, inert gases, and special elements? Such classification is neither satisfactory nor scientific. Another example of indefinite specification is the designation of certain kinds of procedures as instrumental methods. The methods included do involve the use of instruments, but in the strict sense of the term what methods are not instrumental? Thus, an analytical balance is certainly an instrument, and therefore all gravimetric procedures are instrumental methods.

[9] One author, although a devoted Democrat, went so far in his book to emphasize the normal system that he substituted President Harding's much-criticized "normalcy" for the conventional normality.

In precipitimetry the univalent cyanide ion is a confusing case. For titrating silver with cyanide (KCN), the molecular weight is the equivalent weight. For titrating cyanide ion with silver ($AgNO_3$), one mol of the titrant is equivalent to two mols of cyanide. And finally, in the titration of copper, nickel, and cobalt with potassium cyanide, the ratios of cyanide to the respective metals are 7:2, 4:1, and 5:1. Of course, all such uncertainty may be avoided by substituting the molar basis of specifying concentration, or by stating simply the grams of solute per milliliter (or gram) of solution.

Another persistent misunderstanding concerning the normal system of specifying concentration relates to the use of normalities in calculating percentages from titrimetric data. This idea has at least two aspects.

Many seem to assume that a solution having a simple fraction of the normal value, such as $N/5$ or 0.1 N, has some special advantage. Let us consider the relationship

$$\frac{V \times Eq \times 100}{S} = \%$$

in which V is the volume (or grams) of the titrant, Eq is the weight in grams of the desired constituent to which each milliliter (or gram) of the titrant is equivalent, and S is the weight of sample in grams. For two standard solutions of sodium hydroxide, one exactly 0.1000 N and the other 0.1015 N, the respective equivalencies, in terms of hydrochloric acid, are 0.003646 g. and 0.003701 g. It is evident that neither solution has any advantage for calculations, including the possible selection of a direct reading weight of sample. Even if the solution of simple fractional normality had an advantage for calculations, sodium hydroxide is too unstable, and variable in normality toward indicators of different pH ranges, to justify the time and effort for exact adjustment.

For calculating the results of a titrimetric determination many authors imply that one should use the product of the normality of the titrant and the milliequivalent weight of the desired constituent, instead of the simple equivalency shown above. Since equivalency equals normality times milliequivalent weight, it should be clear that every such calculation means an extra multiplication. The required equivalencies might just as well be calculated when the solution is standardized. Either they may be used as such, or, when multiplied by 100, they give the weight of sample to have each milliliter of titrant equal one per cent of desired constituent.

It may be shown, furthermore, that ordinarily the normality need not be calculated in the standardization of the solution. To take a common example, suppose that 30.00 ml. of sulfuric acid is found to react with 0.3000 g. of sodium carbonate. The following relationships are evident at once:

$$H_2SO_4 \text{ concn.} = \frac{\text{g. } H_2SO_4}{1 \text{ ml. } H_2SO_4 \text{ soln.}} = \frac{0.3000 \text{ (g. } Na_2CO_3\text{*)}}{30.00 \text{ ml. } H_2SO_4 \text{ soln.}} \times \frac{98.08 \text{ g. } H_2SO_4}{106.01 \text{ (g. } Na_2CO_3)}$$

$$H_2SO_4\ Eq_{(N)}\dagger = \frac{\text{g. N}}{1 \text{ ml. } H_2SO_4 \text{ soln.}} = \frac{0.3000 \text{ (g. } Na_2CO_3)}{30.00 \text{ ml. } H_2SO_4 \text{ soln.}} \times \frac{28.08 \text{ g. N}}{106.01 \text{ (g. } Na_2CO_3)}$$

$$H_2SO_4\ Eq_{(CaO)} = \frac{\text{g. CaO}}{1 \text{ ml. } H_2SO_4 \text{ soln.}} = \frac{\text{(g. } H_2SO_4)}{1 \text{ ml. } H_2SO_4 \text{ soln.}} \times \frac{56.08 \text{ g. CaO}}{98.08 \text{ (g. } H_2SO_4)}$$

If the normality must be calculated, the simple expression is

$$N = \frac{\text{m. } Eq\ H_2SO_4}{1 \text{ ml. } H_2SO_4 \text{ soln.}} = \frac{0.3000 \text{ (g. } Na_2CO_3)}{30.00 \text{ ml. } H_2SO_4 \text{ soln.}} \times \frac{1 \text{ m. } Eq\ H_2SO_4}{0.05301 \text{ (g. } Na_2CO_3)}$$

Then suppose sodium hydroxide is standardized against the acid. If 30.00 ml. of acid react with 28.00 ml. of base, in the presence of methyl red, we have the following expressions for representative calculations:

$$\text{NaOH concn.} = \frac{\text{g. NaOH}}{1 \text{ ml. NaOH soln.}} = \frac{\text{(g. } H_2SO_4)}{1\text{(ml. } H_2SO_4 \text{ soln.)}} \times \frac{80.01 \text{ g. NaOH}}{98.08 \text{ (g. } H_2SO_4)} \times \frac{30.00 \text{ (ml. } H_2SO_4 \text{ soln.)}}{28.00 \text{ ml. NaOH soln.}}$$

$$\text{NaOH } Eq_{(CH_3COOH)} = \frac{\text{g. } CH_3COOH}{1 \text{ ml. NaOH soln.}} = \frac{\text{(g. N)}}{1 \text{ (ml. } H_2SO_4 \text{ soln.)}} \times \frac{60.04 \text{ g. } CH_3COOH}{14.01 \text{ (g. N)}} \times \frac{30.00 \text{ (ml. } H_2SO_4 \text{ soln.)}}{28.00 \text{ ml. NaOH soln.}}$$

It will be observed that the calculations for the examples given have been made according to a factor-label system in order to show that the procedure is efficient and, if correctly applied, that it necessarily yields answers with the desired labels. It should not be forgotten that the analyst deals for the most part with concrete quantities, measured in specific units, rather than with pure numbers. Also it is to be noted that no recourse is taken to the old, more or less inefficient process of using proportions, a scheme still recommended by too many teachers and writers. The in-line form of the factor-label statement not only eliminates setting up the necessary proportions, step by step, but also it provides for the cancellation of equivalent labels and often of several numbers. The numbers remaining then go into the minimum of multiplications and divisions.

Finally, some writers do not offer sound advice for the use of significant figures in connection with calculations involving international atomic weights. As an example, we may take the preparation of a standard solution by dissolving a weighed amount of solute, such as a simple fraction of an equivalent weight. One writer states that 24.8195 g. of sodium thiosulfate pen-

* The parentheses around the labels show the cancellation of equivalent labels.

† To be read, "Equivalency of sulfuric acid in terms of nitrogen." It is the same as the nitrogen titer of sulfuric acid.

tahydrate should be taken for a liter of 0.1000 *N* solution. Since the calculated amount is based upon international, vacuum-weight atomic weights, the value specified would be incorrect to the extent of the buoyancy correction, assuming that the composition of the material is of sufficiently definite composition to warrant direct weighing. Whether this correction is applied or not, it is a waste of time in such cases to make any effort to work to six significant figures. Ordinary titrimetric measurements, using volumetric ware, seldom yield results more accurate than one part per thousand. For most purposes, therefore, a sensible amount to specify would be 24.82 g. of the thiosulfate.

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CHEMISTRY *in* DENTAL SCIENCE

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THE art of healing, in some form or other, has probably been practiced since the beginning of man's existence. Many of the steps leading to the development of the modern art, and particularly of certain of its branches or specialties, have been taken in comparatively recent times. It is these new accomplishments and trends in the development of the dental division of the healing art which form the basis of this paper.

During a major portion of its recently completed century of existence as a separate profession, dentistry grew away from medicine. It became largely a mechanical art. But during this period of time, it became increasingly apparent that the dividing line between medicine and dentistry is an artificial one; dental conditions are influenced by general physical conditions and vice versa. Therefore emphasis on the biological and biochemical aspects of dentistry is increasing. Moreover, technical advances in other fields influence dentistry, as is well shown by the use of the newer resins in the construction of dentures. To all of this must be added the increased need for dental service and especially for the development of an adequate system of preventive dentistry.

While dental research receives pitifully inadequate financial support, some noteworthy contributions have been made in this field, particularly within the past decade. For the most part, the chemical contributions have not been made by chemists working in isolation but by chemists working in close association or cooperation with bacteriologists, physiologists, pharmacologists, clinicians, and others. The complicated nature of oral diseases and the natural limitations of chemists and other scientists as well make such cooperative activities essential.

Lack of space prevents an enumeration of the many published chemical studies bearing on dentistry and dental problems. It should be understood that the following researches which are to be discussed briefly were not chosen as the "best of the lot" or as representing the only chemical researches in the dental field. They are, however, typical of what has been accomplished. With adequate support and interest, even more interesting and valuable findings may be anticipated.

Hubbell and Bunting (*1*), in a study of a group of children seven to sixteen years of age, found no definite relationship between the calcium and phosphorus contents of the saliva and the occurrence of dental caries. More recently, Karshan (*2*) has reported a statistically significant difference between caries-free and caries-active groups in the percentage of calcium removed from the saliva as a result of treating the saliva with tribasic calcium phosphate. Recently these studies have been extended to Alaskan natives. An examination of the results indicates that immunity to caries in these people is associated with the type of diet used, for a change to the white man's diet is accompanied by the development of carious cavities in the teeth. The findings obtained appear to be valid only for groups and not for single individuals. In other words, neither this test nor others have yet furnished an adequate solution to the problem of individual susceptibility to dental caries. Possibly several factors are involved.

Other chemical tests for caries activity, including those based on differences in rates of acid production in saliva (*3*) and on differences in proteolytic power of the saliva (*4*), have been described. Thus it may be seen that chemical methods are being utilized in an effort to combat and conquer one of the most prevalent and destructive diseases of civilized man. It is of more than passing interest and significance to note that our own *Chemical Abstracts* is the best source of references and abstracts to publications of this nature.

While prevention of dental caries on a large scale has not yet been accomplished, chemical and other scientific findings are of considerable value in this connection. On the basis of these findings, it may be confidently stated that a decrease in the incidence of caries can be brought about by dietary means. Material reduction of highly refined carbohydrates in the diet has been shown to result in a decrease in the rate and extent of the carious process. According to one group of investigators, this may be attributed to the fact that a diet low in these sweet substances does not furnish the required material for acid production by oral microorganisms. Other investigators are of the opinion that the major emphasis should be placed upon the relatively higher proportion of so-called protective vitamins and minerals in such diets. There are indications that both groups may be right.

Other means for the prevention of caries have been presented from time to time. Results obtained by the use of strong chemicals and drugs under various conditions have not been encouraging. In a sense there is one exception to this statement; clinical results indicate that ammoniacal silver nitrate (*5*) is of definite value in arresting incipient dental decay. Under the conditions of professional use, the deposition of silver and silver proteinate from this agent upon enamel or dentin affected by the acids of decay serves to arrest the carious process.

Numerous studies on salivary amylase have been reported in the literature. Mayer (*6*) found that infants, both normal and premature, can digest starch from birth. Meyers and Dellenbaugh (*7*) devised an improved method for studying the amylolytic activity of the saliva. Some of the individuals studied had low amylase activity during periods of gastric distress. In other cases, there was no apparent relationship between the amylolytic activity of the saliva and various pathological states.

Studies relating to chronic endemic fluorosis (mottled enamel) are among the most interesting and striking contributions of chemistry to dentistry. As early as 1913, Gautier (*8*) demonstrated the presence of fluorides in volcanic rocks and water in Italy where mottled enamel was common. The findings were not, however, related to the incidence of mottled enamel. On the basis of many investigations in this country, McKay (*9*) postulated that the etiologic factor in mottled enamel was some rare element present in the water supply. In 1925, he persuaded the community of Oakley, Idaho, where the incidence of mottled enamel was 100 per cent, to change its water supply. Eight years later a survey showed that children born after the change in water supply had been made were free of mottled enamel. Subsequent chemical analysis indicated that the old water supply contained six parts per million of fluoride and the new only 0.5 part per million. The relationship between mottled enamel and fluorides in the water supply has been definitely established by a large number of investigations, both chemical and biological.

Research work is never finished. After it had appeared that the investigation of fluorides in relation to dentistry was satisfactorily completed, field studies (*10*) bearing on the incidence of dental caries in the "mottled enamel" areas were undertaken. The findings indicated that the incidence of dental caries in these areas is lower than in other areas near by where mottled enamel is unknown. Experiments on rats, including biochemical studies, and analytical findings on enamel from sound and from carious teeth also tend to show that fluorides in the diet may be of value in reducing the ravages of dental decay, but not in preventing it absolutely. Research work in this field is now in progress. No practical applications of the findings can be made at present. The workers in the field are acutely conscious of the extremely high toxicity of fluorides.

To this sketchy outline of chemical researches in the dental field, we must add brief remarks concerning two other items of importance. The newer chemical technics are used in dental research. Chemical discoveries which may appear to be totally unrelated to dentistry are nevertheless of significance and importance.

The first item is well illustrated by two recent publications. In the first of these, Manly and Deakins (*11*) used microchemical methods to determine the volume, water, organic and inorganic constituents of normal dentin and certain parts of carious dentin lesions. In the second publication, Grossman (*12*) used the glass electrode to show that aqueous extracts of sound dentin and of carious dentin differ with respect to pH (the mean values obtained were, respectively, 8.16 and 6.51).

The second item referred to above is of greater significance than the space devoted to it might indicate. Possibly it can be illustrated, in part, by simply noting as an example that the brilliant researches of Williams and others culminating in the synthesis of vitamin B_1 (thiamin hydrochloride) are of interest and importance in dentistry. Vitamin deficiency diseases often have oral manifestations. The dentist often sees these manifestations of deficiency diseases before the patient is aware of them.

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PHOTOGRAPHY *in the* COLLEGE CURRICULUM

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INTRODUCTION

PHOTOGRAPHY, literally defined, "to draw by light," and so named by Sir John Herschel many years ago, is now an important tool in science and industry, not to mention its usefulness as a hobby. This ever-increasing popularity of photography has opened up new fields of thought and study and leads one to ask the question: "Is photography adaptable as a course in the college curriculum?"

No one will deny that recent years have brought added interest and enthusiasm for photography from amateur and professional alike. The increased consumption of photographic materials in this country shows that we are becoming camera-conscious. Every enthusiastic photographer will have his own explanation for this increased popularity in the art of photography. The reason given may be the use of photography in journalism, the improvement in modern photographic equipment, or the use of photography in other fields of science and learning.

On account of this popularity of photography, college educators have been asked: "Should photography be included as a subject to be taught in a curriculum already crowded?" In order to answer this question we should consider the problem from the standpoint of the college, and also from the viewpoint of the student taking such a course as a part of his college education.

THE POSITION OF THE COLLEGE

The teaching of photography in the college or university has been practiced by a few institutions for some time (*1*). Several very fine articles have appeared in the literature dealing with the organization of such a course (*2*). A brief course in photography has also been included in some high schools as an elective study for juniors and seniors (*3*). In many cases, although photography is not offered as a credit course, the student has an opportunity for photographic work through the agency of a school camera club. A few colleges and universities maintain their own publicity departments and do not rely on newspaper photographers for their publicity pictures (*4*).

Regardless of the method used to educate the student photographically, certain questions will arise in his mind concerning various fundamental photographic problems. These questions invariably lead back to an understanding of physics or chemistry, since photography is based on the former science to produce the image, and on the latter science to retain the image in a permanent way. The student should, then, have some knowledge of:

1. The phenomena of light as studied in elementary physics.
2. Basic chemical information concerning photographic processes.

It is advisable, therefore, that a course in photography be taught in either the department of chemistry or the department of physics. If that is not possible, instructors in these departments should at least assist in the teaching of the subject.

The average chemist has had enough training in the physics of light to be able to instruct the student thoroughly in the practical side of photography. And many chemists are artistic enough to provide the necessary instruction in photographic composition and lighting. In other words, the teaching staff of the average college already has the necessary man power for instruction in photography. Nevertheless, very few colleges are including photography in their curricula. In 1930, Maphis estimated that there were only four colleges in the United States offering courses in photography that could compare with similar courses presented in the better trade schools (*5*). The number has undoubtedly increased since that time, but no definite figures are given by the New York office of the Association of American Colleges as to the number of colleges teaching photography now. Since a survey of all institutions of higher learning in the country was practically impossible the writer decided to make a survey of all colleges located in one state. The results showed that of the twenty colleges in the state of Virginia, only five, or 25%, offered a course in photography in 1939. One other college planned to start such a course in 1940, but even so, the percentage remains unquestionably low. However, eleven of these same colleges, or over 50%, acknowledged that they did have some sort of dark room facilities available. The results of similar surveys in other states may or may not lead to the same conclusion.

Many college administrators, when confronted with the question of including photography in their curricula, will put the issue aside, stating that the expense involved is too great. Actually, photography may be expensive as a hobby, or it may be practiced in such a way as to fit any pocketbook. Similarly, a one-semester

course in photography can be run economically in the college budget, or it may be lavishly expounded. The dark room is not complicated in its construction and the equipment can be purchased, or it may be put together in the college workshop. A typical student dark room plan for single occupancy is shown in Figure 1, and a student dark room to be occupied by several students

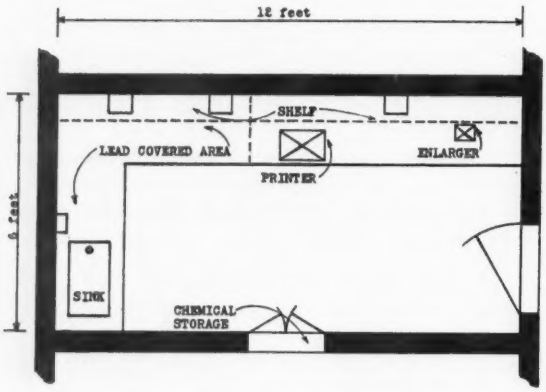

FIGURE 1.—TYPICAL STUDENT DARK ROOM (FOR SINGLE OCCUPANCY)

at the same time is shown in Figure 2. A more expensive layout in the way of a dark room suite is illustrated in Figure 3. These dark room plans utilize different floor areas and equipment. For the most part, the dark room can be equipped from year to year, thereby distributing the burden of expense. The student fee for the course takes care of the films, chemicals, depreciation, etc.

The content of the course in photography may be altered according to the needs of the college or of the department in which it is given. In the survey of Virginia colleges already mentioned, photography was offered by the departments of biology, physics and chemistry, art, architecture and journalism, in as many different institutions. Fortunately, photography is flexible and adaptable enough to be changed to fit the needs desired in any of these fields of learning. This fact makes photography even more attractive to the small college.

THE POSITION OF THE STUDENT

Let us now consider the student's viewpoint relative to the question: "Should photography be included in the college curriculum?" The student himself will probably ask: "Is photography an interesting subject to study? Will photography prove to be of any practical value to me after I have studied it?" And finally, "Is the study of photography very hard?"

To answer the last question first, the study of photography, like any other subject, can be made difficult or it can be presented in a simple way. A comprehensive and detailed treatise on photography will present study problems similar to those in any other science. However, a one-semester course in photography must be brief because of the time element, and therefore simplicity must be practiced in organizing the subject material. Typical lecture-topic headings and laboratory experiments in photography are shown below:

LECTURE SUBJECT MATTER IN PHOTOGRAPHY

1. *General Subject Material*
   - History of Photography
   - Practical Applications
   - Photographic Laws and Customs
2. *Optics in Photography*
   - Light
   - Types of Lenses
   - The Camera
3. *Photographic Films*
   - Types of Emulsions
   - Exposure
   - Orthochromatics
4. *Processing the Film*
   - Dark Room Equipment
   - Chemistry of Development
   - Chemistry of Fixation
5. *Photographic Printing*
   - Types of Printing Paper
   - Contact Printing
   - Projection Printing
6. *Miscellaneous Photographic Material*
   - Composition and Lighting
   - Color Photography
   - Movies

LABORATORY EXPERIMENTS IN PHOTOGRAPHY

1. The Pinhole Camera
2. Lenses—Focal Length
3. Check Student Cameras
4. Prepare Solutions
5. Exposure Latitude
6. Film Processing
7. Contact Printing
8. Projection Printing
9. Reduction: Intensification
10. Copying
11. Lantern Slides
12. Composition
13. Lighting: Portraits
14. Color Photography
15. Individual Projects
16. Individual Projects

Both lecture and laboratory material should be kept fundamental, and some instructors feel that if the student can successfully carry out the operations of photographic developing and printing he has derived sufficient benefit from the course. At any rate, the primary emphasis should be on the fundamental photographic processes, and then, if time permits, a study of some of the side lights may be included.

There are a number of textbooks and references on photography, and the proper text may be chosen to satisfy the needs of the individual institution. The larger publishing houses usually have at least one such book to offer, and a complete list of photographic books is given by Martin in *The American Physics Teacher* for April, 1939. There are also a number of photographic periodicals suitable for student reference work. Several new photographic journals have started publication during the past few months, and one of these, *Collegiate Photographer*, first issued in November, 1939, is designed especially for the college student in photography. Another new periodical is technical enough in content to be used as a reference in advanced work.

Perhaps the best answer to the second question, "Does photography have any practical value for the student?" will come from college graduates who have taken the course themselves. The results of a survey of our students who studied photography during the

four-year period from 1935 to 1938, inclusive, showed that of twenty-eight students registered for photography during this period, seven are utilizing photography to gain all or a part of their remuneration. This means that 25% of the students taking photography during these four years have found practical value in a material and financial way. Four of these graduates are staff newspaper photographers, one is working for a commercial photographer, another graduate takes pictures of filling stations for an oil company, and one graduate has started a department selling photographic equipment and supplies in a store. Twenty of these graduates said they had received benefit from their course in photography as a hobby. When one stops to realize that each of the students mentioned worked only one semester in photography, and that he was really majoring in some other department, the results are even more surprising.

Little need be said regarding the last question, as to the interest aroused by photography in the minds of the students. Their willingness and eagerness to take pictures and to see their finished products are testimonial enough. At the beginning of the course, we usually have some difficulty in keeping students out of the dark room before they have had the necessary training, as they are so eager to develop and print their own pictures. One reason for this interest unquestionably lies in the fact that the student can see an immediate result from his study and work in the dark room. It may be some time before he will actually utilize the data derived from some of his college courses, but in photography the results are forthcoming at once.

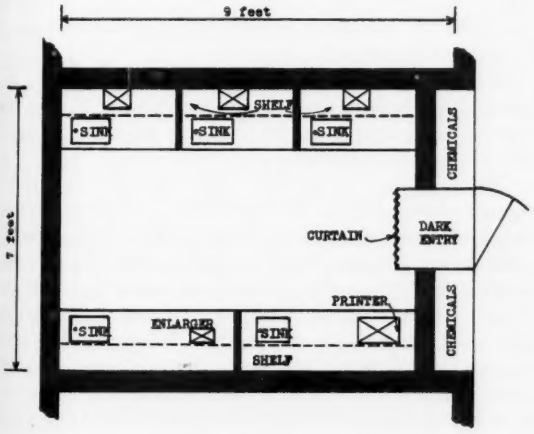

FIGURE 2.—TYPICAL STUDENT DARK ROOM (FOR MULTIPLE OCCUPANCY)

The college course in photography can be made more interesting by including individual student projects near the end of the course as suggested in the list of laboratory experiments. This method has been found successful in several colleges offering short courses in photography (*6*). The student majoring in biology will be interested in a project on photomicrography, the student in chemistry may desire to record photographically the results of certain experiments, and the physics or premedical student may want to try his hand at X-ray photography. The suggestion of an exhibit of prints or a print salon may also serve to stimulate added interest in the course. The problem of student interest is not a serious one in photography, and the instructor will find his charges ready for library reading and other outside assignments in addition to the routine study required.

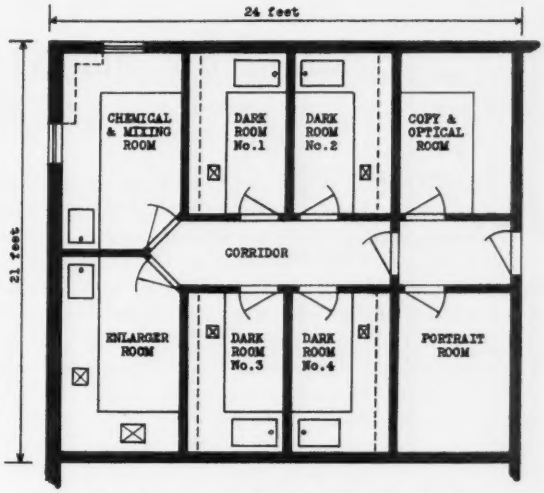

FIGURE 3.—TYPICAL DARK ROOM SUITE

Photography has a future which promises added attractions and new applications to the student, and educators should assist in the promotion of this field of learning.

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COLORING SNAPSHOTS *with* ORGANIC DYES

ELIZABETH E. MURRAY AND MARJORIE P. HANSON

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A PHOTOGRAPHIC print consists of an image of fine grains of silver held on the paper by an emulsion of gelatin. There are several ways of coloring this gray image. One method is by the process of inorganic toning (*2*, *3*, *4*). The print is allowed to react with a solution of chemicals which will replace the silver with a colored insoluble inorganic salt. An advantage of this method is that the colored salt is deposited only where there was silver in the original image; also its density is proportional to the density of the original silver. This method leaves the highlights and supporting paper white, and reproduces the contrast accurately. The main disadvantage of the process is that only a limited number of colors may be obtained.

Photographic prints may also be colored by the use of organic dyes (*2*, *4*), a method which has been under investigation in this laboratory during the past two years.[1] The first step in the dyeing process is to change the silver into some compound that will react with a basic dye. The reagent by which this is accomplished is called a mordant. The mordanted print is treated with a water solution of the dye, which reacts with it to form a fast color.

The choice of possible dyes is wide, although some are more satisfactory than others. The following is a list of dyes used successfully, and the colors obtained from each.

Fuchsine	Red
Safranine Orange	Salmon pink
Acridine O	Yellow
Chrysoidine R	Orange yellow
Guinea Green B	Green
Malachite Green	Bluish green
Methylene Blue	Blue
Methyl Violet	Violet
Bismarck Brown	Yellow brown

For ordinary purposes, the green and blue dyes are the most useful, but for certain pictures, the red and yellow dyes gave striking effects.

The mordant used with the greatest success contains uranium nitrate, oxalic acid, and potassium ferricyanide. The uranium salt formed on the print by the mordant is a chocolate brown color, so that the color of the image formed by the treatment of this print with a dye is strengthened by the brown background. As a consequence, a print dyed with the use of this mordant gives a fairly accurate reproduction of the intensities in the original print.

Another mordant contains potassium iodide and potassium ferricyanide. The image of silver iodide that results from its use is almost colorless. Consequently, when the silver iodide image is treated with a dye, a print is obtained on which only the color of the dye shows. This results in a loss of much contrast and detail. The potassium iodide mordant is, therefore, less useful than the uranium mordant, but it is effective in some cases. Every trace of the silver iodide can be removed by treatment with sodium thiosulfate, leaving an image consisting entirely of the dye (*4*). This treatment was found most useful, however, as a means of removing the blue color on the back of the print caused by the formation of free iodine during the mordanting process.

A third mordant contains copper sulfate, potassium citrate, acetic acid, and potassium thiocyanate. This mordant was unsatisfactory, apparently because the copper salt which is deposited on the image tends to wash away to a certain extent, leaving the final product either blurred or incomplete.

All solutions used in this work were prepared by formulas of the Eastman Kodak Company (*2*), and the general procedure recommended for washing, timing, and so forth, was followed.

The advantage of dyeing over the process of inorganic toning lies in the fact that an almost infinite variety of colors is to be had from dyes. Even when using only a few dyes, a great many shades of color can be obtained by using mixtures of dye solutions in varying proportions, or by allowing the print to react in turn with two or more dye baths. It is possible to dip a print in and out of several baths until the color exactly suits the taste, a procedure which is not possible in an inorganic toning bath because of the greater speed of the reaction. If the print acquires a deeper color than intended, some of the dye can be bleached out by a very dilute ammonia solution (*4*). In the case of uranium mordanted prints, however, it was found that the main effect of the ammonia was to destroy the richness of the brown background, leaving a flatter print.

The depth of color produced by the dye does not vary in accordance with the intensity of the original silver, but has a much smaller range. Therefore dyeing does not reproduce contrast so accurately as does inorganic toning, except when the uranium mordant is used.

The greatest disadvantage of the dyeing process comes from the tendency of the dye to react somewhat with the gelatin and the paper, no matter how carefully all traces of unreacted mordanting solution have been

[1] At the suggestion of, and in consultation with, Dr. Marion E. Maclean.

washed away. Some dyes appear to have the fault to a greater degree than others. Methylene Blue gave the most trouble, while Malachite Green was comparatively easy to work with, giving very clear prints, if used with the proper care.

Sodium bisulfite decolorizes Malachite Green and Fuchsine, except when they have been fixed on a mordanted image of silver iodide. Therefore it may be used to remove these dyes from the highlights and supporting paper of a print on which an iodide mordant has been used (*4*).

Prints of more than one color can be obtained through the process of "double toning" (*3*). After the print has been mordanted and dried, a part is shellacked and the other part is treated with a dye. The shellac is then removed with wood alcohol or acetone. Next the dyed part is shellacked and the undyed part immersed in a dye bath of another color. Theoretically, many colors could be used on one print, but actually the difficulties encountered when one tries to cover small details with the shellac prevent the use of more than three colors from being practical.

It is well to shellac or varnish the finished print, to protect it from the action of hydrogen sulfide, usually present in traces in the atmosphere, which may produce a shiny discoloration on the surface in the course of time, due to the formation of silver sulfide (*1*).

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NOMOGRAPH FOR CORRECTING BAROMETER READINGS FOR TEMPERATURE

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THE following formula, for correcting barometer readings to a temperature of 0 degrees centigrade, has been given by one of the manufacturers of mercurial barometers.[1] If h_0 represents the height of the mercury column at 0 degrees centigrade, and h_t the height at a temperature of t degrees centigrade, then

$$h_0 = h_t (1 - 0.0001614t).$$

The constant 0.0001614 is obtained by subtracting the linear coefficient of expansion of brass from the volume coefficient of expansion of mercury. The formula as stated is for mercurial barometers with brass scales and mounted in brass protecting tubes.

If C represents the correction to be subtracted from the observed barometer reading in order to obtain the correct reading, then from the above equation,

$$C = 0.0001614\ h_t t$$

and

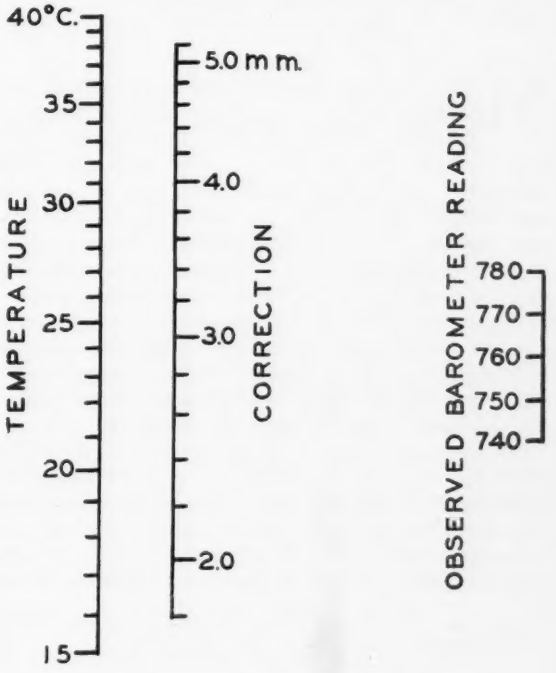
$$\log t = \log C - \log 0.0001614\ h_t$$

This equation corresponds in form to

$$f(x) = F(y) + F'(z)$$

and the accompanying nomograph can be constructed for it by well-known methods.[2, 3]

It has been observed that students become interested in the correction for temperature if a nomograph, such as that shown, is mounted prominently near the barometer. Because of the ease with which it can be interpolated, the nomograph seems to be more convenient than the customary tables.



[1] Circular Ad 87, Central Scientific Company Chicago (February, 1937).
[2] MARSHAL, "Graphical methods," McGraw-Hill Book Co., Inc., New York City, **1921**.
[3] DAVIS, *Chemist-Analyst*, **20**, 6, 4 (1931).

A CAMERA *for* PHOTOGRAPHIC DEMONSTRATION

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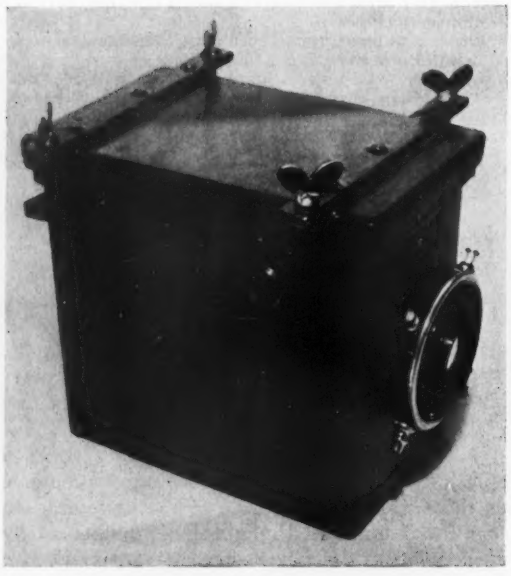
Washington Square College of Arts and Sciences, New York University, New York City



A CAMERA FOR CLASSROOM DEMONSTRATION OF THE PHOTOGRAPHIC PROCESS

MOST demonstrations of photography deal primarily with the characteristics of the sensitive emulsion and fail to illustrate the taking of the picture and the subsequent treatment of the film. Although the taking of the picture itself does not present any difficulty, the development and fixing of the film require special conditions and more time than is usually available in the classroom. To obviate these difficulties, a camera has been constructed in which exposure, development, and fixing can be performed without the removal of the film. These operations are made to yield a direct positive image on "tintype" paper[1] which consists of a sensitive emulsion on a jet-black surface. The portions struck by light are converted to silver on developing, while the unaffected silver halide is dissolved by hypo in the usual way. The silver deposit reflects more light than the black surface on which it lies, thus giving the impression of a positive.

The camera is made of $^1/_{16}$" sheet iron covered with glyptal[2] inside and out to prevent corrosion. Since it was desired to make use of $3^1/_4$" × $5^3/_8$" tintype paper, the camera width and height were fixed by this choice. These dimensions are: height $5^5/_8$", width $3^3/_8$". The length of the camera, *i. e.*, the distance from lens to tintype, is determined by the focal length of the lens. In our case this was $5^3/_4$". To lend rigidity to the box proper a collar $^1/_8$" × $^5/_8$" is soldered around the top.

The camera is made light- and liquid-tight by means of a rubber gasket fitted into the cover. The latter is fastened to the box by four wing bolts as shown in the photograph. The holder for the film consists of two strips of metal, acting as guides, soldered to the walls of the box about 1 mm. removed from the back. Near the front of the camera, a piece of copper tubing, bent in the form of a snake so as to allow the passage of liquid but not light, is soldered to a threaded cup into which a plug with a milled head screws.

The complete experiment is carried out as follows. The camera is loaded in the darkroom. If two No. 2 Photoflood lamps, four feet away from the subject to be photographed, and an *f*/7.7 lens are used, the exposure is 30 seconds. Such an exposure requires that the camera be rested on some firm object such as a stool while taking the picture. The milled cap is then unscrewed and 100 cc. of developing-fixing solution are introduced with the aid of a funnel.

"ONE-SHOT" DEVELOPING-FIXING SOLUTION

(for simultaneous developing and fixing with the same solution)
(5 minutes at 18°C.)
13.3 grams hydroquinone
49.5 grams sodium sulfite
35.5 grams sodium carbonate
106.0 grams hypo
46.0 cc. concentrated ammonium hydroxide diluted to 600 cc.

During this operation, the camera is tilted forward so that the solution will not come in contact with the tintype until all of it has been introduced. The cap is now replaced and the film is developed and fixed by moving the solution back and forth over it for five minutes. While this is going on, the demonstrator has ample time to explain what is happening in the enclosed box. Finally, the wing bolts are removed, the tintype is drawn out and rinsed under the tap. The picture is now ready to show to the class.

If it is desired to cut down exposure time, it is suggested that the tintypes be sensitized in one of the following ways: (1) exposure to mercury vapor for 24 hours, (2) very short exposure to a feeble light, (3) treatment with ammonia water.

[1] The paper is obtainable from the Benson Dry Plate and Camera Company, 166 Bowery, New York City.
[2] Obtainable through the General Electric Company.

Because of the widespread interest in photography and the novelty of the experiment and also because a member or members of the class may participate in it, the above procedure is keenly followed by the students and we believe it succeeds like no other in putting across the elementary principles of the photographic process.

I wish to express my thanks to Dr. William F. Ehret whose suggestions and coöperation made this experiment possible.

SOLUBILITY PRODUCT

A Demonstration Introducing the Common Ion Effect and Formation of Complex Ions

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Northeastern University, Boston, Massachusetts

THE following equilibrium between solid silver acetate and its ions may be used to demonstrate the solubility product principle, the common ion effect, and the formation of complex ions.

$$\underset{\text{(Solid)}}{AgAc} \rightleftharpoons Ag^+ + Ac^-$$

The use of AgAc for this demonstration is not original. Although the solubility product of AgAc, at room temperature, is about 4×10^{-3} its use in this demonstration is justified, from a pedagogical viewpoint, by its effectiveness.

A saturated solution of AgAc is prepared by heating distilled water with an excess of AgAc. On heating, some metallic Ag will be formed causing the solution to darken. Filter while hot and allow the clear filtrate to cool. On cooling, some white crystals of AgAc will settle out to the bottom of the bottle. These may be left in the bottle to show the students that the solution is saturated.

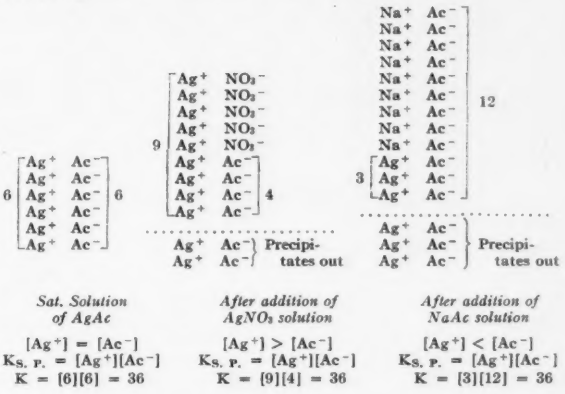
The application of the solubility product principle is best understood in connection with the common ion effect. Pour about 250 cc. of the saturated AgAc solution into a flask or beaker and, with this before the class, discuss the relation:

$$K_{S.P.} = [Ag^+][Ac^-]$$

The common ion effect is demonstrated by adding 10 cc. of a saturated $AgNO_3$ solution to about 250 cc. of the saturated AgAc solution and observing the precipitation of AgAc caused by the addition of the common ion Ag^+. It may be pointed out to the student that the same effect may be produced by increasing the concentration of the Ac^- ions. This may be demonstrated in another flask or beaker by adding 10 cc. of a saturated NaAc solution to about 250 cc. of the saturated AgAc solution. In both cases about 20–30 seconds elapse before a fairly heavy precipitation of AgAc occurs.

To demonstrate the fact that common ions are necessary for the precipitation, 10 cc. of a saturated $NaNO_3$ solution are added to about 250 cc. of the saturated AgAc solution. No precipitation occurs.

These changes may be explained to the student as follows:



It is obvious that the numbers here used as concentrations of the Ag^+ ions and Ac^- ions do not represent gram ion concentrations. These numbers are merely used to increase the effectiveness of the discussion and to enable the student to obtain a more thorough understanding of the principle discussed. The relationship between activities (effective concentrations) and concentrations may also be pointed out.

Having caused the precipitation of the AgAc by the addition of common ions, *i. e.*, by increasing the concentration of either the Ag^+ ions or the Ac^- ions, it may be demonstrated that the precipitated AgAc can be caused to go back into solution by decreasing the Ag^+ ions or the Ac^- ions. This can be shown by adding to the precipitated AgAc some concentrated HNO_3, to form the slightly dissociated HAc, and, to another portion, some concentrated NH_4OH, to form the silver-ammonia complex ions.

LECTURE DEMONSTRATIONS *in* GENERAL CHEMISTRY

SAUL B. ARENSON

University of Cincinnati, Cincinnati, Ohio

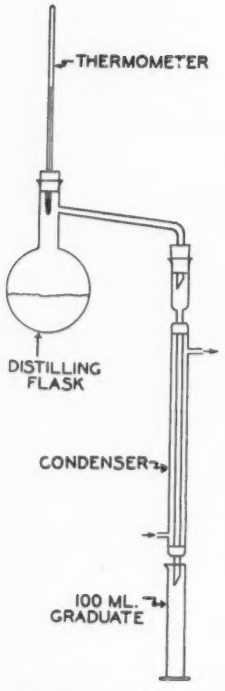


FIGURE 1.—SIMPLE DISTILLATION

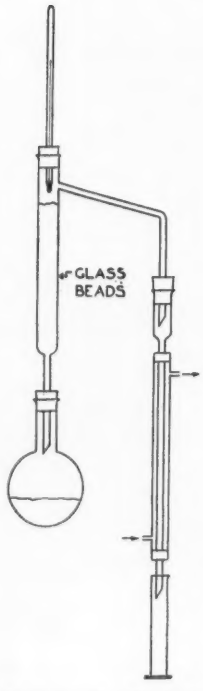


FIGURE 2.—PACKED COLUMN DISTILLATION

PRACTICALLY every teacher of general chemistry has many "pet" lecture demonstrations which he has developed for use with his freshman classes. The following were selected from the many experiments sent to me as a result of a letter addressed to teachers in 250 universities and colleges. It is hoped that these contributions will be of sufficient interest and value to encourage other teachers to submit their experiments, for a continuation of this series.

1. DISTILLATION VERSUS RECTIFICATION[1]

This experiment consists in preparing a known solution of two liquids, and then attempting to separate them, first by simple distillation, and second, by distillation through a packed column.

Procedure.—(1) Set up the simple distillation apparatus as diagrammed in Figure 1. Prepare a known solution by taking 50 ml. of chloroform in the 100-ml. graduated cylinder, and adding to it enough toluene so that the total volume is 100 ml. Transfer the solution to the distilling flask and distil the mixture at a fairly vigorous rate, catching the distillate in the 100-ml. graduate. Record the temperature as the volume of distillate reaches 5 ml., 10 ml., and so on until 95 ml. are received or until the distillation is complete.

(2) Set up the packed column distillation apparatus as diagrammed in Figure 2. Place 100 ml. of the known solution made as before in the Erlenmeyer flask and distil slowly, again recording temperature and volume of distillate. The rate of heating must be controlled to some extent; it should be fast enough so that a drop of distillate forms every second or so, but not so fast that the tower is flooded and condensed material is unable to return to the boiling flask.

(3) Plot boiling point vertically versus volume of distillate. (Figures 3 and 4 are sample curves.) Look up the accepted boiling points of chloroform and toluene and include these as the points corresponding to 0 ml.

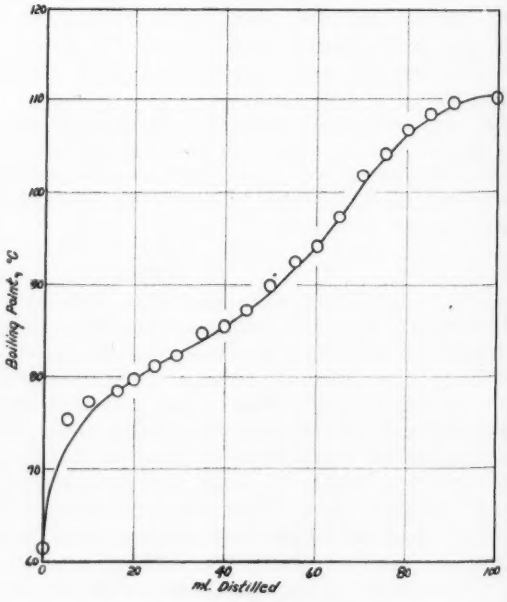


FIGURE 3.—SIMPLE DISTILLATION

[1] Contributed by Gilbert Ford Kinney, Instructor of Chemical Technology, Pratt Institute.

and 100 ml.[2] The horizontal axis now corresponds to per cent distilled and the purity of any portion of the distillate can be estimated (roughly, of course) from its boiling point on the vertical axis.

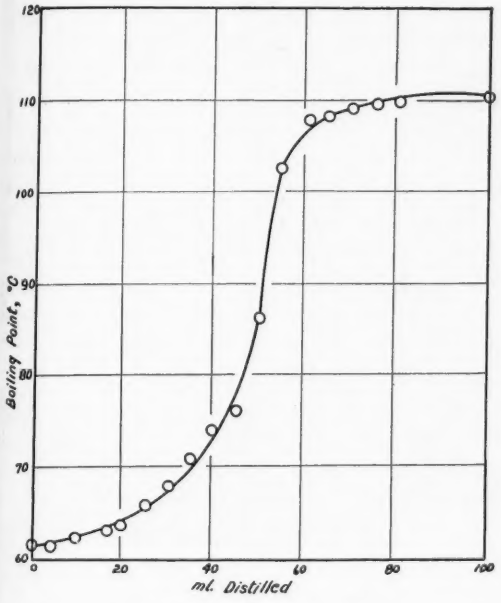


FIGURE 4.—PACKED COLUMN DISTILLATION

Suggested Questions for Discussion.—(1) Suppose the distillate from the simple distillation were divided in four equal fractions as it came over. Estimate the purity of each fraction from its boiling-point curve and discuss what would happen if each fraction were redistilled.

(2) Explain how it is physically impossible to do as is often proposed by those with no understanding of the problem, "to hold the temperature half way between the two boiling points, and catch all of the more volatile liquid as it boils off."

(3) Repeat question one for the distillation through the packed column.

(4) Compare the efficiency of the two methods of distillation, and compare the heat requirements of the two methods for equivalent separations.

2. EQUILIBRIUM PROCESSES IN WATER SOLUTION[3]

In the process of developing the principles of dynamic equilibrium and chemical change involving ions in water solution, it is obviously good practice to demonstrate each type of reaction and each principle separately and to use as many different ions and different reagents as possible. However, after the students have been well introduced to the main reactions and to the important principles, the inclusion of a few more complex experiments, in which a solution may be treated successively with several different types of reagents, may not only arouse considerable curiosity but also promote logical thinking on the part of the student. The following experiment seems to create unusual interest and is thought-provoking.

Samples of ferric nitrate, ferric sulfate and ferric chloride are shown to the class and the color of each salt noted. About 20 or 25 g. of ferric nitrate are dissolved in 100 cc. of water and the color of the solution noted. A 20-cc. sample of the solution is saved for reference and to the remainder in a large demonstration tube is added concentrated nitric acid, drop by drop, until most of the color is eliminated. A second 20-cc. sample is saved and the main part of the solution treated with concentrated hydrochloric acid until maximum color is obtained. Following this same procedure the solution is successively diluted, treated again with concentrated hydrochloric acid, with concentrated phosphoric acid, with potassium thiocyanate solution, and finally with a solution of potassium fluoride.

Treatment	*Results*	*Explanation*
$Fe(NO_3)_3$ dissolved	Solution colored	$Fe(OH)_3$ by hydrolysis
HNO_3 added	Color fades	Mass action, neutralization
HCl added	Color returns	$FeCl_3$ molecule colored
Solution diluted	Color fades	Increase of ionization
HCl added	Color deepens	Mass action, common ion
H_3PO_4 added	Color fades	Complex ion, $Fe(PO_4)_2^{---}$, weak
KCNS solution added	Deep red color	$Fe(CNS)_6^{---}$ ion weaker
KF solution added	Color disappears	FeF_6^{---} ion still weaker

3. VAPOR PRESSURE–TEMPERATURE CURVE FOR A LIQUID

The apparatus illustrated (Figure 5) overcomes the difficulties usually encountered when demonstrating to beginning students accurately the change in vapor pressure of water with the temperature. The evacuated vapor-pressure tube shown comprises a dry side separated from a compartment containing about 1 cc. of water by a "U" of mercury. The wet compartment and the entire "U" is immersed in water contained in an ordinary outer jacket of a Victor Meyer apparatus, which can be heated from below. The vapor pressure is determined by measuring the difference in the height of the two mercury columns. A large bulb is provided on the outside of the water bath. Any moisture that may be carried over to the dry side after several demonstrations may be frozen out by immersing this bulb in a suitable freezing mixture; *i. e.*, solid carbon dioxide and acetone.

4. BAROMETRIC PRESSURE, VAPOR PRESSURE, AND VAPOR PRESSURE LOWERING

The apparatus (Figure 6) is similar to ones usually described. However, two modifications, both of which have been found helpful, have been made: The apparatus (tube, support, and bottle of mercury) is hinged at

[2] Ordinarily these points fall on the curve very nicely, but it might be necessary sometimes to include corrections for thermometer stem, barometer, etc.

[3] This and the three following experiments were contributed by Walter R. Carmody, Assistant Professor of Chemistry, Reed College.

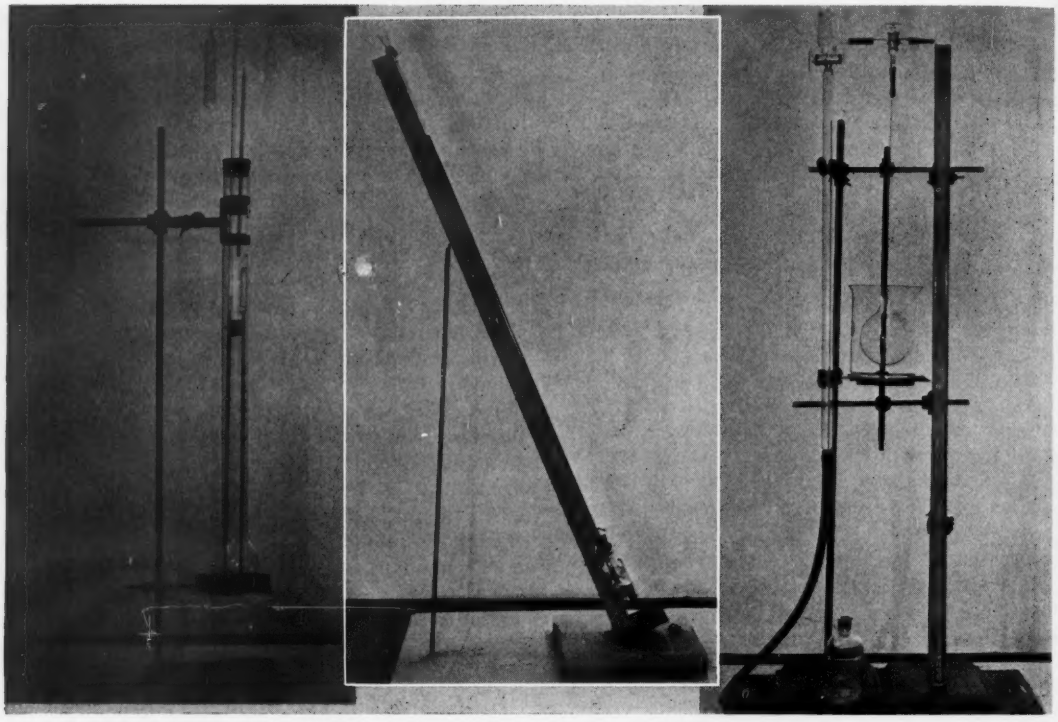


FIGURE 5 FIGURE 6 FIGURE 7

the bottom so that it may be tipped to any desired angle; also a stopcock and funnel are provided at the top of the tube so that liquids or solutions may be introduced easily.

The barometric pressure, the vapor pressure of a liquid, and the lowering of the vapor pressure may be demonstrated with little manipulation of the apparatus. The tube is filled with mercury by tipping it somewhat and applying suction at the top from an ordinary aspirator pump, the stopcock being turned when the mercury has just reached the top. The tube is locked in the upright position and is ready for the demonstration. The fact that there is a vacuum above the top of the mercury can be demonstrated by tilting the tube until the mercury fills it to the top. The tube is locked in the upright position and the height of the mercury column read. A drop or two of a liquid such as ether is placed in the funnel and introduced into the tube by careful manipulation of the stopcock. The height of the mercury column is again read and the vapor pressure of the liquid calculated. About a cubic centimeter of a solution of oxalic acid in ether is introduced into the tube and the new vapor pressure determined. The effect of the original drop of solvent on the larger amount of solution may be neglected.

5. DEMONSTRATING BOTH THE LAW OF BOYLE AND THE LAW OF CHARLES BY ONE APPARATUS

The novelty of this setup (Figure 7) lies in the fact that one compact apparatus may be used to demonstrate both laws. It comprises a gas measuring buret (with aspirator flask attached), and an ordinary 500-cc. round-bottomed flask, both connected through a three-way stopcock to a manometer. For obvious reasons the manometer and connecting tubes are made of glass tubing of very small bore.

Boyle's Law may be demonstrated by manipulating the aspirator flask, which is filled with mercury, and the stopcock at the top of the buret until there are about 30 cc. of air at atmospheric pressure in the 100-cc. gas buret. The gas buret is now connected with the manometer and pressure and volume of the enclosed gas are read. The pressure is reduced by lowering the aspirator flask, and pressure and volume readings are made at appropriately spaced points until the capacity of the buret is reached or until the aspirator flask reaches the table.

In the demonstration of Charles' Law the stopcocks are manipulated so that the central air bulb is open to the atmosphere. The beaker is filled with boiling water and then the top three-way stopcock turned so that the bulb is connected with the manometer. The water in the beaker may be stirred with a thermometer, and readings of pressure and temperature taken simultaneously at appropriate intervals as the water bath is cooled. With the use of ice, a temperature range of nearly 100 degrees may be obtained with a corresponding pressure range of about 200 mm. of mercury.

(To be continued)

The FILAMENT-BEARING BALANCE

JACK DE MENT

1907 South East 48th Avenue, Portland, Oregon

THE balance is regarded by many as the most valuable instrument in the scientific laboratory. While balances and other forms of apparatus for weighing substances are present in most laboratories, the use of the delicate fine-edged bearing type of balance is often restricted to those laboratories where finances are not of prime importance. There is an indication that in many cases the price of a weighing machine is proportionate to the sensitivity of that machine. The substitution or construction of a special type of very sensitive and yet economical form of bearing will in many cases enhance the value of the ordinary chemical balance in the laboratory where the use of the delicate analytical balance is prohibitive due to price. Also, the use of this different type of bearing will often merit its use in so-termed "sensitive" balances; that is, an ordinary knife-edge bearing balance may be converted into a semimicro balance by use of the *filament-bearing principle.*

It is obvious that in most cases the less contact between moving parts of a balance, with a subsequent minimum of friction, the more sensitive the machine will be. Using this idea, it is possible for the instrument maker or mechanically minded laboratory worker to modify balance bearings in the following manner: It was found that extremely delicate balances could be constructed by the use of long balsa wood beams suspended on bearings made of a single human hair strung through the eye of a needle! These experimental balances were surprisingly sensitive. Fractions of a milligram could be weighed with ease. The human hair, needle-eye type of bearing was very strong, for in most cases the use of maximum loads (20–40 grams) did not impair its efficiency or affect its sensitivity. One such balance, using a human hair for a bearing, has been in use for over three years. The same hair has been suitable for moderate use during this period. While in many cases the use of the wood beam, human hair, needle-eye type of bearing might be warranted, it is suggested that either wire net or thin sheets or tubes of very light metal be used for beams. In many cases the use of aluminum and its alloys, as well as alloys of beryllium and others, has provided very suitable beams. However, the ordinary laboratory balance as constructed commercially will usually be appropriate for conversion to the filament type of bearing.

The bearing and its construction will be more or less at the discretion of the worker but the general principle of using the beam suspended upon a tense filament is utilized. Choice of the material for the fiber involves consideration of type and intensity of usage. Human hairs will often suffice in machines where work is of the semimicro type. Care must be used with hairs or other fibers of an organic origin, due to the fact that gases and volatile solids and liquids tend to act upon the fiber with a subsequent weakening or rupture. Metal filaments (wires) are perhaps most suitable in that hardness, high tensile strength, and small size are the desirable features which may be incorporated in such a filament. For ordinary purposes the use of steel music wires of 00000 to 00000000 (0.0100″ to 0.0083″) gage will generally be suitable. It is obvious that the type of balance as well as the use to which the filament bearing is to be put is the determining factor in the construction of filament-bearing balances. Factors of sensitivity will obviously vary but sensitivity may be regulated by tension upon the supporting filament.

The bearing rest may be of several types. The use of a needle eye fixed to the beam with the fiber strung through it at right angles constitutes a very practical arrangement. However, sensitivity is often increased by the use of another wire strung on the beam and resting at right angles to the supporting wire and parallel to the beam.

In using a filament bearing for increasing sensitivity of an ordinary balance, or perhaps in the construction of a new type of micro balance, several factors might be considered as fairly basic:

1. Mechanical effects of use upon the bearing. Soft materials or highly ductile, brittle, elastic, or weak substances are obviously unsuitable.

2. Size of the filaments and the area of contact, as well as load and tension of the filament, will often determine or sometimes restrict the sensitivity.

3. Chemical action upon the filament bearing should be reduced to a minimum by use of desiccants and of inactive materials for construction.

Kopp was rather short of stature and generally stood on a raised platform. He did not face the audience squarely, but turned sideways to the right, and then with a good voice, and without a break, he would get off one of those long, involved sentences until he was red in the face. There was one particular sentence in which he took great pride because it covered the lower half of one printed page, with the finishing verb on the next. We were supposed to applaud him on the conclusion of that sentence. We never neglected to do so, and he would smile in appreciation.—ALFRED SPRINGER

UPPER LIMIT *of* TEMPERATURE

CARL ROSENBLUM

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WHEN Charles's Law is taken under consideration in the classroom and it is pointed out that because of the proportional decrease of volume with temperature, the lowest possible temperature is about −273°C., the student naturally asks, "What is the highest possible temperature?" A search of textbooks reveals no answer to this problem. Therefore, the teacher is thrown on his own resources and may answer honestly, "It is probably very high, but I don't know how high," or be sarcastic and say, "What's the matter, isn't it hot enough for you?" or resort to some of the other escapes which have been used.

By the use of two equations and some simple mathematics, a value is obtained which may logically be considered the upper temperature limit. That there is such a limit seems possible because, although the known temperature of stars goes up to millions of degrees, these high temperatures seem to cluster and are not scattered haphazardly in astronomical figures on the temperature scale. A few of these high temperatures are given in the table below:

TEMPERATURE OF STARS[1]

Star	*Spectrum*	*Surface temperature*	*Central temperature*
Capella	GO	5,200°K.	9,000,000°K.
Cephei	F9	5,200°K.	6,000,000°K.
V Puppis	B1	19,000°K.	42,000,000°K.
Sun	GO	6,000°K.	40,000,000°K.
Krueger 60	MO	3,100°K.	32,000,000°K.

An upper limit may be obtained mathematically by considering the nature of heat and its effect on molecules. The molecules of a substance are not at rest. At ordinary temperature, the molecules of a gas in air move at about $^1/_3$ mile per second. As the temperature increases, so does the molecular velocity. The relationship between the velocity of the molecules and temperature may be obtained from the kinetic equation of a gas and the ideal gas law.

The kinetic equation is:

$$PV = {}^1/_3mnu^2 \qquad (1)$$

where m is the mass of a single molecule, n is the number of molecules, u is the mean velocity in cm./sec., P is the pressure (force exerted upon a unit area), and V is the volume of a cube containing the molecules.

The ideal gas law is:

$$PV = nRT \qquad (2)$$

where R is a constant having the value of 8.315×10^7 ergs per mol per degree Kelvin and T is the temperature in degrees Kelvin.

For one mol equation (2) may be rewritten:

$$PV = RT \qquad (3)$$

From equations (1) and (3) we get:

$$PV = RT = {}^1/_3mnu^2 \qquad (4)$$

and since we are considering one mol, mn equals the molecular weight, M

$$RT = {}^1/_3Mnu^2 \qquad (5)$$

R is a constant having the value given above. Our formula in (5) becomes (solving for T):

$$T = 10^{-7}/25Mu^2 \qquad (6)$$

This is the relationship of temperature and velocity of molecules. Assuming a molecular weight of 1, if we find a limiting value for u we have a limiting value for T. It has been considered that the speed of light, which is about 186,360 miles per second, is the maximum speed of any object. Therefore, if we substitute this speed for u we obtain the upper limit of temperature, about 3.58×10^{12} degrees Kelvin, or, roughly, 3,580,000,000,000 degrees.

Of course, to be accurate, this is the upper limit only for atomic hydrogen. If we use any other substance of higher molecular weight our temperature limit would be higher. However, it is known that in regions of high temperature, the lower molecular weights predominate. Therefore, we assume that should we approach the upper limit not only would the higher molecular weights be broken down but we would have a predominance of protons.

In order for the upper temperature limit to be reached, all the molecular energy would have to be transformed into heat. This is not true in nature, as a great deal of the energy is dissipated in the form of light, both visible and invisible, and in other forms of radiation.

[1] BAKER, "Astronomy," 2nd ed., D. Van Nostrand Co., New York City, 1933, p. 420.

Helmholtz is said to have enjoyed hearing that he "looked like Bismarck."—ALFRED SPRINGER

The EQUILIBRIUM CONSTANT EQUATION

A Concrete Solution of a Teaching Difficulty

WILLIAM A. DOW

Grand Rapids Junior College, Grand Rapids, Michigan

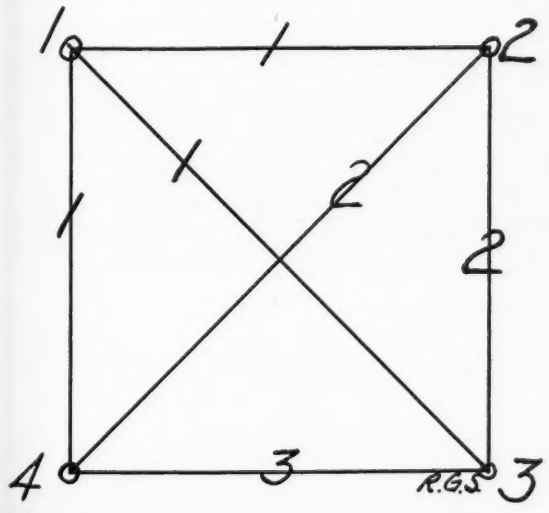

FIGURE 1

IN THE mathematical expression of the Law of Chemical Equilibrium, it has been generally difficult for the student of elementary college chemistry to understand clearly why it is necessary to use the *total concentration* of a reactant raised to some power, *e. g.*,

$$2HI \rightleftharpoons H_2 + I_2$$

$$\frac{[H_2] \times [I_2]}{[HI] \times [HI]} = K$$

The student cannot readily understand why [HI] in the above expression must represent the *total concentration.* I believe this can be explained simply and clearly without sacrificing either mathematical principles or chemical theory.

It may be presented to a class by starting with the assumption that the velocity of the reaction to the right is proportional to the number of collisions between the hydrogen iodide molecules per unit of time, explaining that on the average only a certain per cent of the total contacts will result in chemical change, since the molecules have different kinetic energies at any instant and only those at an energy level above a certain point are capable of reaction. Then proceed by means of drawings to show that the number of chances of collision is proportional to the velocity of the reaction and to the total molecular concentration raised to that power represented by the coefficient standing before its formula in the balanced equation.

Let 0 represent a hydrogen iodide molecule. Taking four molecules, it can easily be shown (by Figure 1) that the total number of chances of collision per unit of time is six.

Molecule No. 1 2 3 4
No. of collisions = 3 + 2 + 1 + 0 = 6

Another diagram (Figure 2) is drawn for a molecular concentration of eight molecules representing the number of chances of collision per unit of time as twenty-eight.

Molecule No. 1 2 3 4 5 6 7 8
No. of collisions = 7 + 6 + 5 + 4 + 3 + 2 + 1 + 0 = 28

Therefore, for x molecules of hydrogen iodide the chance of collision will be $(x - 1) + (x - 2) + (x - 3) + \ldots 1$. The general formula of such a series is,

$$\frac{(x - 1)x}{2}$$ *

* HOGNESS AND JOHNSON, "Qualitative analysis and chemical equilibrium," Henry Holt and Co., New York City, 1937, Part I, p. 51.

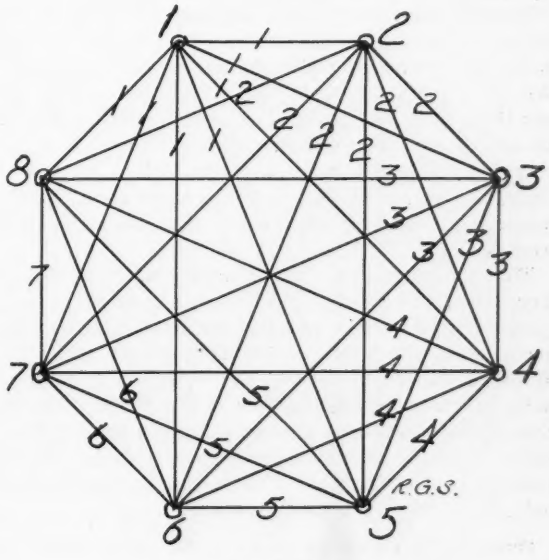

FIGURE 2

Testing this formula, using the second illustration (Figure 2) above where $x = 8$

$$\frac{(8-1)8}{2} = 28 \text{ chances of collision}$$

Since the number of chances per unit of time is proportional to the number of actual collisions, it follows that the number of collisions is also proportional to $(x-1)x$, where x represents the number of molecules of hydrogen iodide in the system. For all practical systems x would represent a very large number of molecules, so $(x-1)$ may be considered equal to x, and $(x-1)x$ equal to x^2. Since x represents the total molecular concentration of the reactant, hydrogen iodide, it follows that the velocity of the reaction to the right is proportional to the total concentration of the hydrogen iodide raised to the second power.

Although the above reaction represents a specific type, other types lead to modified general mathematical formulas all pointing to the same conclusion, namely, that the total concentration of each reactant must be used and that this total concentration must be raised to that power represented by the coefficient standing before the formula of the substance in the balanced equation.

A SIMPLE TEST *for* STRAIGHT LINE RELATIONSHIPS

DONALD E. BABCOCK

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MANY students have at times desired a rapid method for determining whether or not the relation sought in the physical chemistry laboratory was a straight line function. The long and tedious plotting of data in various types of coördinates to obtain the solution of problems in physical chemistry or other branches of chemistry or other sciences, is exasperating when graph paper is not available.

Through any two points a straight line may be drawn, but more than this amount of data is necessary to determine whether a straight line exists in a graphic plot of physico-chemical data. The introduction of any third point will suffice to complete the necessary conditions required for the solution of the problem involved. Because any three points determine a triangle, the only condition in which these three points can lie in a perfectly straight line is where the area of the triangle formed by them is equal to zero.

To accomplish the solution, once this condition is recognized, one need only remember from analytical geometry that the area of a triangle is obtained by taking one-half the value of the determinant made up of the coördinate points of the triangle. If four or more points are used, the area of the polygon is still zero, if the points lie in the same straight line, and the value of the determinant formed by them is also zero. In order to show the method of testing described in this note, let us solve a typical problem.

PROBLEM: In a first order process the following observations were made on the product x of a reaction:

Time in Seconds	t	0	10	20	30	40	∞
Concentration	x	0	60.8	97.7	119.9	133.4	153.8
	$a-x$	153.8	93.0	56.1	33.9	20.4	0.0

SOLUTION OF THE PROBLEM OF TEST OF LINEARITY OF THE GRAPHIC PLOT: In first order reactions the reactant controls the rates of the reaction. The concentration of the reactant is then determined by the values of $(a-x)$, for the x values found in the problem are the values for the product only.

First order reactions are linear if log $(a-x)$ values are plotted against t.

$(a-x)$	$Log\ (a-x)$	t
93.0	1.9865	10
56.1	1.7490	20
33.9	1.5302	30

			Plus values	*Minus values*
Area = ½	1.9865	10	17.4900	
	1.7490	20	30.6040	39.7300
	1.5302	30	59.5950	52.4700
	1.9865	10		15.3020
			107.6890	107.5020

Difference = 0.19.

Area = 0.095 or 0.10, which for all practical purposes is a straight line, if one considers the possible errors in measurement. In tests of other points more widely spread apart the areas obtained will be found to be negligible.

A case may be found wherein the area obtained will increase progressively as a larger number of points are taken. If such is found to be the case, the graphic plot of these points may be a curve or made up of two different straight lines which some further testing will reveal.

If graph paper is not available, the foregoing test is of considerable utility. With the aid of a slide rule, it is readily applied.

MODIFIED ATOMIC VOLUME PLOTS

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University of Illinois, Urbana, Illinois

WHILE the periodicity exhibited by the elements is admirably illustrated by the original Lothar Meyer atomic volume curve, it is often difficult for the student to visualize the relationship between this plot and the Mendeleeff type of periodic table. A more direct correlation may be obtained by superimposing the atomic volume curve on the long form of the periodic table. The advantages of this modification of the periodic system have already been pointed out (*1*), and the arguments advanced in its favor are substantiated by combining it with the original example of periodicity.

Such a plot is given in Figure 1 where the values have been calculated from the 1940 International Atomic Weights and the most recent density data (*2, 3, 4, 5*) and usually refer to the solid elements at 20°C. Hydrogen and helium are purposely omitted due to their rather anomalous atomic volumes, and dotted line interpolations are used where data are lacking. The value for the region 57 to 71, inclusive, is an arithmetical average for thirteen of the rare earth elements and is included to show that no discontinuity exists in the sixth period.

While this plot, like all similar ones, is in error by not always giving data for the same physical state, it is, nevertheless, of value in showing the similarity between any two periods and in bringing to the student's attention the fact that the elements within a given family occupy corresponding positions on the various curves.

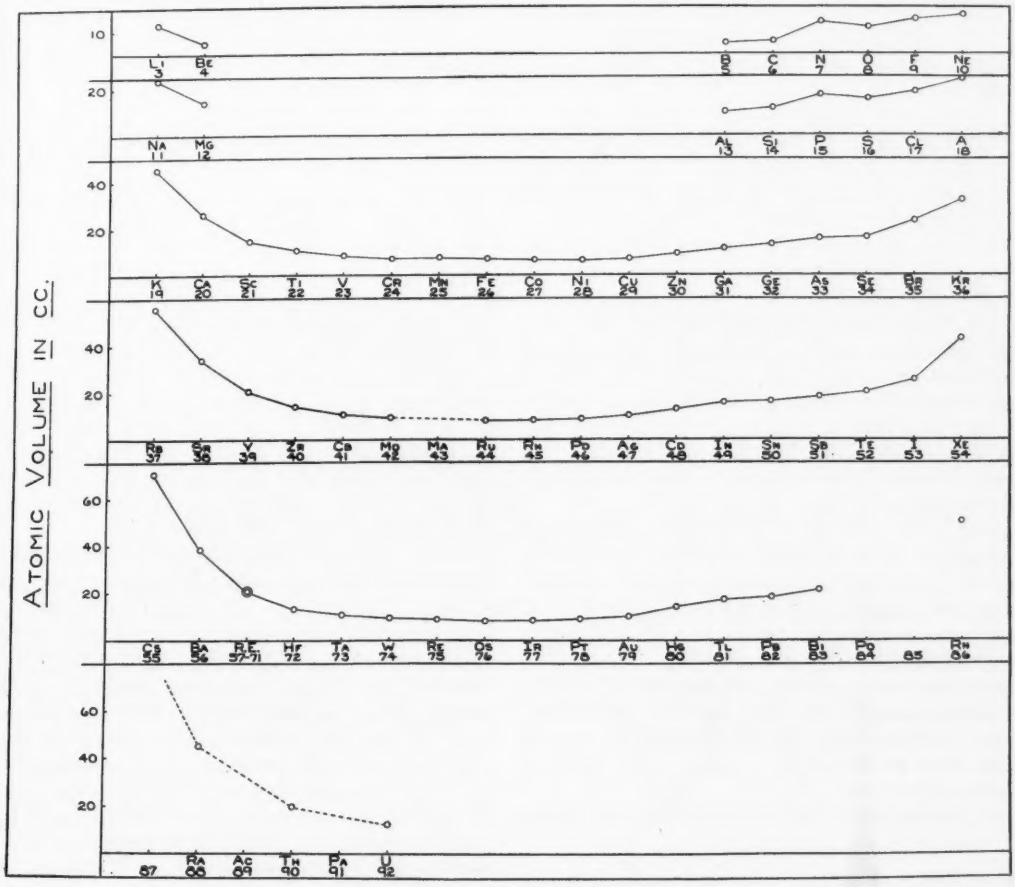

FIGURE 1.—THE PERIODIC SYSTEM

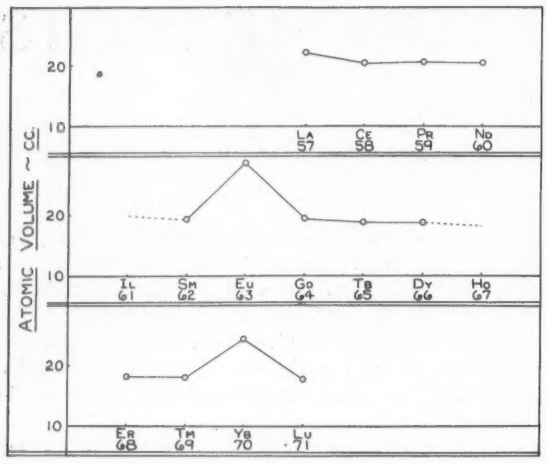

FIGURE 2.—THE RARE EARTH METALS

THE RARE EARTH METALS

The existence of periodicity within the rare earth group has already been demonstrated (*6*, *7*). In Figure 2, a modified atomic volume plot constructed from the data of Klemm and Bommer (*5*) is given. Included in this plot are lanthanum and lutecium, although these two elements are sometimes referred to as merely transition elements rather than rare earths.

While periodicity is less striking in this plot, there is definite evidence of its existence, and the graph serves as a convenient supplement to Figure 1. It is of especial interest that not only do europium and ytterbium, the elements showing the pronounced maxima, differ from the others in crystal structure (these two being cubic, the rest hexagonal), but also they are the ones most readily convertible to the divalent condition.

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THE PLACEMENT OF PHYSICS AND CHEMISTRY IN HIGH SCHOOLS

ELTON T. REEVES

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HUNTER[1] in his book, "Science Teaching," notes the fact that more than half the schools offering physics and chemistry give them in the preferential order of *chemistry* followed by *physics*. That is, the majority of schools offer chemistry as a junior subject and physics as a senior elective.

This would seem to the writer to be wrong on at least three major counts.

First and foremost, physics is easier than chemistry. The content of the material presented is in itself of a lower grade of difficulty than that contained in chemistry. The reactions to be observed in a physical world are less complex in nature than those occurring in a chemical world.

The science of physics is more mathematical (at least in its presentation in high schools) than is chemistry. If physics is offered to juniors, the students are one year nearer to their mathematics, which should result in pedagogical economy.

Second, the laboratory work in physics is much easier than that in its young offspring. The technics to be learned are simpler, and form good background material for the more difficult laboratory situations arising in chemistry. Generally speaking, it is harder for the student to learn the proper use of pipet, buret, the analytical balance, and all the other tools of chemical experimentation than it is for him to become adept in the use of meter sticks, inclined planes, and the rough balances of the physics laboratory.

Third, the implications and applications of chemistry are broader and deeper in the students' lives than are those of physics. However true it may be that one lives in accordance with fundamental physical laws, the fact remains that to the student, chemistry's contributions to his life are more spectacular. At approximately the period that most pupils spend in their senior year of high school there is a startlingly rapid maturation of the power of logical thought. The more complex chemical laws are more readily understood than they would have been the year before.

It has been the writer's experience repeatedly that juniors and seniors fare about alike in physics, but that *juniors are always handicapped in chemistry.*

[1] HUNTER, "Science Teaching," American Book Co., New York City, **1934,** pp. 48–9.

« « « HIGH-SCHOOL NOTES » » »

THE CHEMISTRY EXAMINATION OF THE COLLEGE ENTRANCE EXAMINATION BOARD

IN 1937 the College Entrance Examination Board appointed a Commission to revise the requirements for the one-unit examinations in physics and chemistry. The membership of the Commission, which submitted its report at the April, 1940, meeting of the Board, follows:

Dean John T. Tate, University of Minnesota (Chairman)
Doctor Otis E. Alley, High School, Winchester, Mass.
Mr. Raymond B. Brownlee, Stuyvesant High School, New York City
Dean Janet H. Clark, University of Rochester
Mr. John C. Hogg, Phillips Exeter Academy, Exeter, N. H.
Professor Erwin B. Kelsey, Yale University
Mr. Alfred R. Lincoln, Technical High School, Springfield, Mass.
Professor Duane E. Roller, Hunter College
Professor Francis W. Sears, Massachusetts Institute of Technology
Professor Mary L. Sherrill, Mount Holyoke College
Mr. Howard A. Taber, Hotchkiss School, Lakeville, Conn.

The report consists of proposed syllabi in physics and chemistry. The chemistry syllabus is printed below in the belief that it will be of interest to all teachers of chemistry. This syllabus, together with the physics syllabus, will be presented to the Board for action in October. In the meantime the Executive Secretary of the Board will welcome suggestions and criticisms from those interested. Communications should be addressed to the office of the College Entrance Examination Board, 431 West 117th Street, New York City.

THE CHEMISTRY SYLLABUS

The following suggested redefinition of the requirement in chemistry indicates the nature and extent of the *basic* preparation considered necessary for college work. It is estimated that from two-thirds to four-fifths of the school year will be required to cover the basic topics suggested in the minimum syllabus given by Part I and Part II. Part III is intended to show how the basic material of Parts I and II can be amplified. Additional specific material designed to meet the needs of the community and adapted to the level of the student body should also serve to enrich the basic course. Questions on topics beyond this suggested area will not be included since it is felt that the science will be more effectively taught if the instructor is given greater latitude in the selection of topics.

The syllabus is divided into two sections:

(1) a minimum syllabus, Part I and Part II;
(2) an extension syllabus, Part III, which is subdivided into
  (*a*) commercial chemistry,
  (*b*) theoretical chemistry, and
  (*c*) organic chemistry.

Candidates will be examined on the minimum syllabus only. Quantitative problems may be set upon those topics marked with an asterisk (*).

In order that the objectives of the course of study may be fully realized, it is essential that the study of chemistry be accompanied by individual laboratory work as well as by class demonstrations. The laboratory work should occupy approximately one-third of the time devoted to chemistry and it should continue throughout the whole course. A list of experiments is not submitted as it is believed that the experiments will need to be varied according to the facilities of a particular institution. The arrangement of the syllabus does not imply a teaching sequence.

PART I. GENERAL CHEMISTRY

I. Chemical Changes.
  A. Element, compound, mixture.
    1. Chemical change versus physical change.
    2. Significance of terms—atom, molecule, radical.
    3. Types of chemical reactions.
    4. Electrochemical series—limited to displacement reactions.
  B. Balancing of simple equations.
  *C. Quantitative relationship in chemical reactions.
    1. Significance of symbol, formula, equation.
    2. Laws of combining proportion.
    3. Percentage composition.
    4. Problems based on chemical equations:
      (*a*) weight relationships,
      (*b*) volume relationships.
    5. Neutralization (quantitative). Normal solutions.

II. Physical Properties of Solids, Liquids, and Gases.

A. Kinetic molecular theory—relation between temperature and speed of molecules. Differences between solids, liquids, and gases from kinetic molecular viewpoint.

*B. Gases:

1. Effect of changes of temperature and pressure on the volume of gases. Explanation in terms of the kinetic theory.
2. Partial pressures of gases in a mixture—related only to vapor pressure of water.
3. Reduction to standard conditions (including vapor pressure of water).
4. Avogadro's Law: derivation of gram molecular volume from a knowledge of the density and molecular weight of a gas.

III. Periodic Law.

Brief treatment giving variation in properties of the elements as one proceeds horizontally and vertically through periods and families. Anomalies.

IV. Structure of Atoms.

A. Units of structure.

Proton, neutron, electron, characterization as to mass and charge.

B. Atomic number. Nuclear charge and arrangement of electrons (hydrogen through calcium).

Isotopes (hydrogen, chlorine).

C. Explanation of periodicity in properties of elements in terms of atomic structure.

D. Ionic valence and its relationship to inert gas structure (hydrogen through calcium).

E. Chemical combination explained in terms of atomic structure.

1. Electrovalence—combination and displacement; reactions in terms of electron transfer (oxidation-reduction).
2. Covalence—sharing of electrons in formation of un-ionized molecules.

V. Electrolytes.

A. Physical evidence of dissociation in fused salts and bases and in water solutions.

B. Complete dissociation of salts and strong bases.

C. Ionization of acids.

1. Ionization of acids by reaction with water. Distinction between a proton and the hydrated hydrogen ion (hydronium ion).
2. Degree of ionization of weak acids—ionic equilibrium.

D. Completion of ionic reactions by:

1. Formation of a slightly ionized product:
2. Formation of an insoluble gas or solid.

E. Hydrolysis of salts (reaction of ions with water).

F. Electrolysis of water solutions.

PART II. DESCRIPTIVE CHEMISTRY

In general, the study of any element should be developed in the following sequence: history, occurrence, preparation (most important laboratory and commercial methods), properties (physical and chemical), uses, and identification. Historical treatment should be limited to cases where it offers a sound teaching approach and where it is of particular significance in the study of an element; for example, as an introduction to oxygen and hydrogen.

Similarly, the study of the important compounds of the elements should include preparation, properties (physical and chemical), uses, and identification.

As illustrative of a typical study of an element and its important compounds, the topic *Nitrogen* is given in expanded form at the end of Part II.

I. Chemistry of Some Non-metals and Their Common Compounds.

A. Oxygen.

B. Hydrogen.

C. Water.

1. Composition by weight and volume.
2. Purification.
3. Chemical reactions:
   (*a*) With oxides, basis of classification of metals and non-metals;
   (*b*) With salts to form hydrates.
4. Solutions:
   (*a*) Significance of terms—saturated, unsaturated, molar.
   (*b*) Interpretation of solubility curves.

D. Carbon (allotropes).

1. Carbon dioxide and carbonic acid; types of carbonates; test for a carbonate.
2. Carbon monoxide.

E. Halogen family.

1. Chlorine; hydrogen chloride and hydrochloric acid; hypochlorous acid.
2. Bromine, iodine, fluorine, and the hydrogen compounds, as compared with chlorine and hydrogen chloride.
3. Tests for chloride, bromide, and iodide ions.

F. Sulfur.

1. Hydrogen sulfide, sulfides.
2. Sulfur dioxide—sulfurous acid, sulfites, bisulfites.
3. Sulfur trioxide—sulfuric acid, sulfates, bisulfates.

4. Tests for sulfide, sulfite, and sulfate ions.

G. The atmosphere.
1. Air as a mixture.
2. Nitrogen and the rare gases.

H. Nitrogen compounds.
1. Ammonia—test for ammonium ion.
2. Oxides of nitrogen—nitric oxide and nitrogen dioxide.
3. Nitric acid.
Test for nitrate ion.

II. Chemistry of a Typical Metal.

A. Sodium and its compounds.
1. Sodium hydroxide.
2. Sodium chloride.
3. Sodium carbonate and sodium bicarbonate.
4. Sodium nitrate.

III. Nitrogen (Outlined in Expanded Form for Illustrative Purposes).

A. History.
B. Occurrence.
C. Preparation.
1. Atmospheric nitrogen.
2. Pure nitrogen.
D. Properties.
1. Physical.
2. Chemical.
E. Uses.
F. Compounds.
1. Ammonia.
(*a*) Laboratory preparation.
(*b*) Commercial preparation.
(1) Synthetic (Haber).
(2) Cyanamid.
(*c*) Ammonium compounds.
(*d*) Test for ammonium ion.
2. Oxides of nitrogen.
(*a*) Nitric oxide.
(1) Preparation by:
(a) oxidation of ammonia (Ostwald),
(b) reduction of nitric acid.
(2) Identification.
(*b*) Nitrogen dioxide.
(1) Preparation by:
(a) oxidation of nitric oxide,
(b) reduction of nitric acid,
(c) heating of nitrates.
(2) Identification.
3. Nitric acid.
(*a*) Preparation.
(1) Laboratory.
(2) Commercial: oxidation of ammonia (Ostwald).
(*b*) Properties.
(1) Physical.
(2) Chemical.
(a) Reaction of concentrated and dilute acid on
(i) metals,
(ii) non-metals,
(iii) salts.
(*c*) Test for nitrate ion.

G. Nitrogen Cycle.

PART III. EXTENSIONS

Parts I and II give the basic material for preparation for college work. It is recommended that the basic material be supplemented by topics from Part III and also by various items of current and local interest.

I. Commercial Chemistry.

A. Chemistry of four metals and their common compounds: aluminum, iron, zinc, and copper.
1. Occurrence and extraction of these four elements from their ores.
2. Simple reactions of these elements and identification of their ions.

B. Fuels.
1. Coal gas, producer gas, water gas.
2. Acetylene.
3. Petroleum and natural gas; distillation and cracking process.

II. Theoretical Chemistry.

A. 1. Oxidation-reduction by electron transfer, as illustrated in the reactions of Part II.
2. Ozone, hydrogen peroxide, other peroxides, atomic hydrogen.

*B. Determination of:
1. Equivalent weight.
2. Molecular weight.
3. Application of these to the determination of atomic weights.

C. Equilibrium, mass action law and principle of Le Chatelier as applied to:
1. Synthetic ammonia (Haber process),
2. Contact process for preparation of sulfuric acid,
3. Common ion effect with weak electrolyte.

III. Organic Chemistry.

A. Simple organic reactions.
B. Foods.
1. Components: carbohydrates, fats, proteins, vitamins.
2. Hydrolysis. Uses of starch and sugar.
3. Fermentation.

«« OUT OF THE EDITOR'S BASKET »»

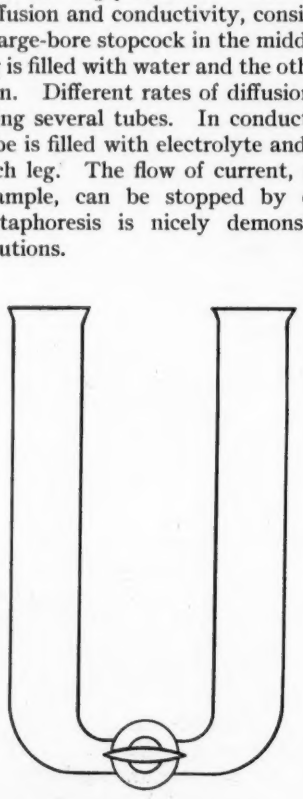
In this section we propose to include, from time to time, items of interest which come to the Editor's attention, but which cannot, for one reason or another, be given space as regular published articles. We take this opportunity to invite specific contributions to this section and to thank the many authors who will, in the future, we feel confident, permit their manuscripts to be abstracted here.

PROFESSOR Ed. F. Degering, of Purdue, thought he observed that students seated in the front of the class consistently won better grades than those in the rear, and, with the usual show of scientific curiosity, proceeded to test the observation. Although this seems, at first glance, to reduce the process of "educational experimentation" to a complete absurdity, the situation is not as bad as that, quite. A survey of the grades for five years, in a sophomore class in organic chemistry in which the alphabetical seating arrangement was reversed in the second semester (a total of 1500 cases), yielded the final result that a student seated in the front of the room has twice the opportunity of getting a high grade that a student has who sits in the rear. And conversely, a student in the rear is in twice as great danger of flunking. Degering calls this "The Newtonian Principle in the Classroom." Newton's principle, in case you need reminding, has to do with natural gravitation. We would suggest, however, that it is a better example of another well-known law: The intensity of illumination varies inversely as the square of the distance from the source. It is to be noted that the generalization does not apply to the extremely brilliant students, however, which only goes to show that you can't keep a really good man down, no matter where you seat him.

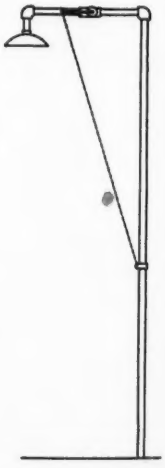
● Mr. M. W. Harowitz, of Virginia Polytechnic Institute, is a photographic enthusiast and makes the interesting suggestion of using color photography in the teaching of qualitative analysis. Color pictures may be taken of precipitates on opened filter papers as well as of solutions in beakers illuminated from below, and afford permanent exhibits or demonstrations for students. Naturally, proper attention must be given to the arrangement and illumination of objects and to exposure time, but information on the technic of color photography is readily accessible.

● The following suggestion for the removal of "frozen" rubber stoppers, contributed by Silvester Liotta, of C. C. N. Y., will be useful to some: An applicator stick, match, or toothpick is sharpened to a point, moistened with strong sodium hydroxide (10 per cent or more), and inserted between the stopper and the glass. Sodium hydroxide is a good lubricant and after working around both ends of the stopper in this way the glass tube can be twisted and easily pulled out.

● Philip S. Chen, of Atlantic Union College, contributes the following picture of a demonstration apparatus for diffusion and conductivity, consisting of a U-tube with a large-bore stopcock in the middle. For diffusion, one leg is filled with water and the other with a colored solution. Different rates of diffusion can be compared by using several tubes. In conductivity experiments the tube is filled with electrolyte and electrodes inserted in each leg. The flow of current, shown by a lamp, for example, can be stopped by closing the stopcock. Cataphoresis is nicely demonstrated with colloidal solutions.



DIFFUSION APPARATUS



LABORATORY SHOWER

● The illustration of a laboratory shower, shown above, is contributed by Harold S. King, of Dalhousie University, and has one feature which may prove novel. The use of a lever-operated valve is by no means new, but attaching the chain to the lower part of the upright makes it possible to operate the shower by a pull, swing of the arm, or simple lunge of the shoulder.

• Dr. Barnet Naiman, of C. C. N. Y., has recently made a survey of courses in inorganic quantitative analysis, based upon a questionnaire from twenty-nine colleges and universities, some of the results of which may be of interest. Among the various determinations required, those which were regarded as most fundamental were: chloride, both gravimetric and volumetric; acid-base titration, generally including a soda ash determination; volumetric iron, usually with permanganate. Less common: unknown acid and gravimetric iron.

Recent additions to laboratory technic included the use of new oxidizing agents, such as ceric sulfate, "redox" indicators and absorption indicators. A number of important changes in the classroom approach were noted. In addition to the common emphasis on physico-chemical principles a number of newer points are receiving added attention, such as co-precipitation, oxidation and reduction potentials, pH and the selection of indicators.

A few novel arrangements of the curriculum were observed: quantitative analysis preceding qualitative; introductory qualitative analysis in the first year, followed by a full year of advanced qualitative and semi-quantitative; a year of advanced analysis consisting of both qualitative and quantitative; qualitative analysis in the first year, elementary physical, followed by quantitative, in the second. Qualitative analysis was only seldom found to be the laboratory work of the first-year course.

Grades on unknowns are generally given out to students promptly, but in some quarters there is a feeling that this practice leads to "unknowns" becoming "knowns." The general procedure is to fix grades on a normal distribution curve with a different gradient for each determination, based sometimes upon an absolute deviation from an accepted value and sometimes upon a relative deviation (parts per thousand).

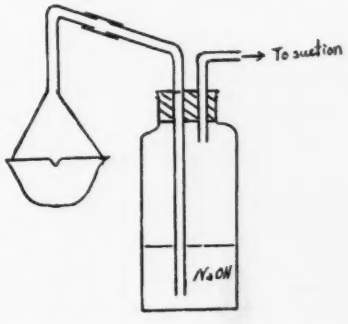
• There came to our desk recently a copy of a little periodical that impressed us so favorably that we would like to give it the notice it richly deserves. This was the second number of Volume II of *The Delaware Chemist*, as published by the Department of Chemistry and edited by the senior students in chemistry at the University of Delaware. We have seen a few other similar publications but this one could well serve as a model for any other group ambitious to try its hand at a job of local publishing. From research on "Orthanilamide" to "The Role of Salts in Life," its articles are stimulating and interesting. One, entitled "The Chemist Spins a Thread," is one of the most readable accounts of the chemistry of modern textiles we have seen. Congratulations, Delaware! We hope to hear more from you. And, incidentally, we would like to see what other local groups can offer in this line, and to make a complete collection of such periodicals.

AN INEXPENSIVE HOOD FOR INDIVIDUAL STUDENTS

I. LIN

Fukien Christian University, Foochow, China

IN CONCENTRATING sulfuric acid and removing nitric and hydrochloric acid in qualitative analysis, and in destroying the organic matter in the Kjeldahl digestion, the acid fumes produced necessitate the use of a hood. To use a hood which is remote from the working table is quite inconvenient as carrying apparatus and idly watching the evaporation proceed wastes much time. Also the running of a big motor in the hood for the sake of one person is not economical. It will be a simple matter to invert on the gas outlet an ordinary funnel connected to water pump. The gas produced dissolves in the running water. If the duration is rather long or if the fumes attack the rubber tubing, a wash bottle containing sodium hydroxide must be inserted. In case the condensed liquid may drip back into the evaporator with the danger of carrying with it undesirable matter from the rubber, the stem of the funnel must be bent and the connection made as shown in the accompanying figure.



« « « WHAT'S BEEN GOING ON » » »

STRUCTURE OF RARE EARTH ELEMENTS

AT THE Conference on Spectroscopy held in July at the Massachusetts Institute of Technology, Dr. W. F. Meggers, Chief of the Spectroscopic Section of the National Bureau of Standards, presented a summary of recent spectroscopic determinations of the electronic configurations of the rare earth elements. Table 1 includes the results of workers at Princeton and M. I. T., as well as at the Bureau of Standards. Because of difficulties in obtaining pure samples, and due to the enormous number of lines in the spectra, no reliable catalog or interpretation of their emission lines has been possible until recently, and all information concerning their structure has been purely theoretical. The premature addition of *f*-type electrons to fill or half fill the *f* shell explains in part the so-called anomalous valence of two, exhibited by samarium, europium, thulium, and ytterbium. It also explains the discrepancies between theoretical and experimental ground states, because the first theoretical predictions neglected to take account of this tendency of larger shells to hasten completion. Furthermore, the definition of a rare earth element as one which has three incomplete shells must be withdrawn, since it appears that the inner shell (4) is completed with ytterbium.

—LAURENCE S. FOSTER

WHALE, herring, and sardine oils are to be processed for aircraft lubricants by a new plant being built by the Japan Oil and Fat Company. We take it that fish oil is to go up.

Judging from soap exports for September, 1939, which increased 44% to about $1,000,000, the rest of the world is going to clean up.

The Bensel Brice Corporation of Hollywood announces a process, that is entirely satisfactory for local distribution, for packing fish, meat, fruits, and vegetables in Pliofilm bags and then cooking in the regular canning equipment. By this process about fifty per cent of the container cost is saved, which amounts to $8.00 per thousand.

According to C. M. A. Stine, of du Pont de Nemours and Company, there are ten thousand different products being produced from cellulose, and the industry is still in its infancy.

—ED. F. DEGERING

BOMBARDMENT OF URANIUM WITH FAST AND SLOW NEUTRONS

SHORTLY after the announcement of the discovery of the neutron (Chadwick, 1932) and of artificial radioactivity (M. and Mme. Joliot-Curie, 1934), Fermi and his co-workers (1934) announced that heavy elements, such as thorium and uranium, are capable of capturing neutrons and thereby becoming highly radioactive. The activity was found not to be associated with the transmutations of the target element into any of the elements between lead (atomic number 82) and uranium (atomic number 92) and they reached the startling conclusion that transuranic elements, (atomic numbers 93, 94—) had been synthesized. This interpretation was held to be correct quite generally until January, 1939, when Hahn and Strassmann demonstrated the presence of elements of about half the atomic weight of the uranium among the products of such bombardments. These observations of the *fission* of the heaviest elements were confirmed almost immediately in laboratories scattered throughout the world, and the existence of Fermi's transuranic elements was open to very serious question. On June 7, 1940, however, E. McMillan, of the University of California, and P. H. Abelson, of the Carnegie Institute of Washington, D. C., were able to announce that elements 93 and 94 actually are produced, but instead of having properties thought to characterize eka-rhenium and eka-osmium, their chemical properties seem to correspond more closely to those of uranium itself, thus opening the possibility that as a consequence of inner-shell building *a new series of elements* analogous to, but chemically dissimilar to, the rare earths (atomic numbers 57–71), makes its appearance, with element 93 as the first member. The series of transmutation reactions is evidently:

$$_{92}U^{238} + {}_0n^1 \xrightarrow{23\ min.} {}_{93}U^{239} \longrightarrow [93]^{239} + \beta$$

$$[93]^{239} \xrightarrow{2.3\ day} [94]^{239} + \beta$$

No alpha or beta ray activity, or any evidence of fission, has been detected which can be associated with the decay of $[94]^{239}$. It seems to be very long-lived. Except for amplification in

TABLE 1

DISTRIBUTION OF ELECTRONS FOR RARE EARTH ELEMENTS

		Ground state												*Singly ionized state*										*Observed valences*
		Theoretical										*Experimental*						*Experimental*						
											Term						*Term*						*Term*	
Shell	*No.*	1	2	3	4				5			6		4	5			6		4	5			6		
Element					*s*	*p*	*d*	*f*	*s*	*p*	*d*	*s*		*f*	*s*	*p*	*d*	*s*		*f*	*s*	*p*	*d*	*s*		
58	Ce	2	8	18	2	6	10	1	2	6	1	2	^3H							2	2	6		1	^4H	3, 4
59	Pr	2	8	18	2	6	10	2	2	6	1	2	^4K							3	2	6		1	^5I	3, 4, (5)
60	Nd	2	8	18	2	6	10	3	2	6	1	2	^5L							4	2	6		1	^6I	3
61	Il	2	8	18	2	6	10	4	2	6	1	2	^6L													—
62	Sm	2	8	18	2	6	10	5	2	6	1	2	^7K	6	2	6		2	^7F	6	2	6		1	^8F	2, 3
63	Eu	2	8	18	2	6	10	6	2	6	1	2	^8H	7	2	6		2	^8S	7	2	6		1	^9S	2, 3
64	Gd	2	8	18	2	6	10	7	2	6	1	2	^9D	7	2	6	1	2	^9D	7	2	6	1	1	^{10}D	3
65	Tb	2	8	18	2	6	10	8	2	6	1	2	^8H													3, 4
66	Dy	2	8	18	2	6	10	9	2	6	1	2	^7K													3, 4
67	Ho	2	8	18	2	6	10	10	2	6	1	2	^6L													3
68	Er	2	8	18	2	6	10	11	2	6	1	2	^5L													3
69	Tm	2	8	18	2	6	10	12	2	6	1	2	^4K	13	2	6		2	^3F	13	2	6		1	^3F	(2), 3
70	Yb	2	8	18	2	6	10	13	2	6	1	2	^3H	14	2	6		2	^1S	14	2	6		1	^2S	2, 3
71	Lu	2	8	18	2	6	10	14	2	6	1	2	^2D	14	2	6	1	2	^2D	14	2	6		2	^1S	3

details, this phase of the artificially induced radioactivity in $_{92}U^{238}$ by bombardment with both fast and slow neutrons seems to have been cleared up.

Even more astonishing is the explanation of the origin of the elements of low atomic weight. It was noted very early that two atomic products of fission were ejected in opposite directions at extremely high velocities, thus carrying enormous quantities of energy. Because of their low kinetic energies, particles of $_{92}U^{239}$ and $[93]^{239}$ remain in the layer of target material where they are produced, but the products of fission escape with such violence that they may be caught on tissue paper a few centimeters from the target and examined chemically. The energies are of the order of magnitude of 200 Mev. or 4.6×10^{12} calories per gram atomic weight of uranium. It is this tremendous quantity of energy emitted that has given rise to the hope that atomic fission may be the source of "atomic power."

In April, 1940, Nier of Minnesota and Booth, Dunning, and Grosse of Columbia announced that sub-microscopic quantities of the natural isotopes of uranium, $_{92}U^{234}$, $_{92}U^{235}$, and $_{92}U^{238}$, had been separated by means of a mass spectrograph and subjected individually to neutron bombardment. It was found that only isotope $_{92}U^{238}$ undergoes fission with "thermal neutrons"; $_{92}U^{238}$ is also capable of absorbing "thermal neutrons," but is transmuted to element $[93]^{239}$ just as with more energetic neutron projectiles. The exact sequence of events after the capture of a slow neutron by $_{92}U^{235}$ has not been worked out, but fission is accompanied by the escape of many more fast neutrons than were captured, which makes possible the initiating of a chain reaction. This can occur only in the presence of non-absorbing objects of collision, such as water, which reduce the kinetic energy of the secondary neutrons down to thermal equilibrium values. This possibility of a chain reaction has removed all but one barrier to the development of "atomic power." The problem of separating the uranium isotopes on a commercial scale must yet be solved. By mass spectrographic means, it has been estimated that 75,000 years would be required to collect a single pound! The usual chemical and physical processes of separating isotopes have given too small a fractional difference to be practicable.

The complex particle, formed by the capture of a thermal neutron by $_{92}U^{235}$, bursts in the inconceivably short time of 10^{-12} seconds into at least two atomic particles, the nature of which remains uncertain because of their short half-life. They may be radioactive isotopes of Cs (40 seconds) and Rb (80 seconds) which have been shown to be the parent substances of Ba (90 minutes or 15 hours), and Sr ($7^1/_2$ hours), all of which have been isolated from the products. The process of fission is highly complex and in addition to the fast neutrons ejected, isotopes of the following elements have been produced in the disintegrations of atomic species resulting from fission: $_{35}Br$, $_{36}Kr$, $_{37}Rb$, $_{38}Sr$, $_{39}Y$, $_{40}Zr$, $_{41}Cb$, $_{42}Mo$, $_{43}Ma$, and $_{51}Sb$, $_{52}Te$, $_{53}I$, $_{54}Xe$, $_{55}Cs$, $_{56}Ba$, and a rare earth which may be $_{57}La$. The emission of the fast neutrons has been shown to follow the process of fission and may arise as a result of nuclear excitation following the beta decay of the nuclear fragments.

The absurd extent to which "atomic power" has already been publicized is illustrated by a recent "headliner." On July 27, WBZ's new 50,000-watt transmitter (at Hull, Massachusetts) was turned on by a Geiger-Muller counter set off by the fission of $_{92}U^{235}$. When the neutron source, a stainless steel capsule containing $5000 worth of radium and beryllium, was brought close to the disc of uranium, three distinct clicks were broadcast to what the studio engineers undoubtedly hoped was an unseen audience of several million.

As an antidote to the following articles, LANGE, "Fast new world," *Colliers*, July 6, 1940, and O'NEILL, "Enter atomic power," *Harpers*, June, 1940, the student is referred to the excellent summary, "Is atomic power at hand?" by POTTER in *Scientific Monthly*, **50**, 570–1 (1940) and the more mature reader, to "Nuclear fission," *Rev. Mod. Physics*, **12**, 1–20 (1940). (For original articles, consult the indexes of *Physical Review* and *Chemical Abstracts*.)

—LAURENCE S. FOSTER

REMOVING INK SPOTS[1]

STANLEY C. BUNCE

Lehigh University, Bethlehem, Pennsylvania

THE effectiveness of chemical reagents in the removal of two-week-old spots of different kinds of inks was investigated. Results with the best of these reagents are indicated in the table.

For the "blue-black" inks, the reagents used remove only the temporary dye, not the iron tannate. For these, the best and most common of the permanent inks, it is suggested that permanganate be used to remove the temporary dye. This should be followed with oxalic acid (10 per cent) to discharge the permanganate and dissolve the iron tannate. Washing with weak ammonium hydroxide will insure against harmful effects of the acid reagents on the fabric or paper.

	Type of ink				
Reagent	*Permanent blue dyestuff*	*Permanent red dyestuff*	*Permanent black dyestuff*	*Logwood*	*Temporary dye of blue-black*
Sodium pyrophosphate (saturated)					Good
Sodium hydrosulfite (10%)	Good				
Sodium bisulfite (10%)	Good				Good
Sodium hypochlorite (10%)	Good	Good	Complete	Complete	
Sodium perborate (5%)	Complete				Good
Acid permanganate (10%)	Complete	Complete	Complete	Complete	Complete
Acid permanganate (5%)	Complete	Complete	Good	Complete	Complete
Acid permanganate	Complete	Good	Good	Complete	Complete

[1] These results are abstracted from a report of work performed at Lehigh University under the direction of Doctor Robert D. Billinger.

« « « « RECENT BOOKS » » » » »

THE CHEMIST AT WORK. *Roy I. Grady* and *John W. Chittum*, Professors of Chemistry, College of Wooster, Wooster, Ohio, and others. First Edition. JOURNAL OF CHEMICAL EDUCATION, Easton, Pa., 1940. xv + 454 pp. 51 figs. 14 tables. 13 × 19.7 cm. $3.00.

The purpose of the book is to give the reader a representative picture of the chemist at work and to serve as a vocational guide to the opportunities in the field of chemistry; to aid the teacher with his guidance problems and to help the student in arriving at a decision regarding his life work.

The book is made up of a series of 53 articles by successful practical chemists in various fields. The preface is by Dr. R. E. Rose. Chapters I to XXXV were collected and edited by Professors Grady and Chittum. Chapters XXXVI to XLII include relevant articles collected and edited by Dr. Otto Reinmuth, retired editor of the JOURNAL OF CHEMICAL EDUCATION. Chapters XLIII to LIII include articles collected and edited by Dr. Reinmuth and comprise the Symposium on the Training and Opportunities for Women in Chemistry conducted by the Division of Chemical Education at the ninety-eighth meeting of the American Chemical Society at Boston. A 32-page appendix contains a chart, or trade analysis, of the chemical technician indicating what he does, what he uses, and what he must know.

The editors have prefaced each of the first 33 chapters with a brief statement of the experience and training of the contributors. Each contributor then discusses the general nature of his field, following this with the details of his typical daily laboratory activities and often indicating how problems confronting him are solved. The writers conclude their articles by discussing the personal characteristics and training essential for their type of work. The advice given to prospective chemists is sound, frank, and practical.

For intelligent vocational guidance both the teacher and the student must become familiar with the industry, its social implications, and its demands upon the chemist. THE CHEMIST AT WORK is one of the first books to make a serious attempt to help the student and teacher with this problem.

The authors have included a wide variety of occupations. The contributors are experts in their fields and include some who have been out of college but a few years as well as many who have spent their lives in the profession. Sixteen chapters are by successful women chemists and will be found invaluable in dealing with the guidance of women chemistry majors.

A few of the early chapters of this book are rather brief and sketchy, the contributors failing to do full justice to their opportunities; otherwise the articles are well written and stimulating. The value of the book could have been enhanced by a more adequate discussion of salaries and employment opportunities, but the reviewer appreciates the difficulty of treating these topics.

The book should be read by all of those students who contemplate majoring in the field. It will also be of cultural interest to the layman.

C. S. ADAMS

ANTIOCH COLLEGE
YELLOW SPRINGS, OHIO

QUALITATIVE ANALYSIS BY SPOT TESTS. *Fritz Feigl*, Director of the Research Laboratory, Société Belge de Récherches, Gand.; Emeritus Professor of Analytical and Inorganic Chemistry of the University of Vienna. Second English edition translated from the third German edition by *Janet W. Matthews*. Nordemann Publishing Co., Inc., New York City, 1939. xv + 462 pp. 27 figs. 15 × 24 cm. $7.00.

The first English edition of QUALITATIVE ANALYSIS BY SPOT TESTS, which appeared in 1937, is well known to chemists. The second English edition is a translation of the third German edition. It contains many new results of the author's work in the field; in addition, corrections of the first edition have been made. The book is indispensable to all those engaged or interested in qualitative analysis, both in organic and inorganic fields.

WARREN C. JOHNSON

UNIVERSITY OF CHICAGO
CHICAGO, ILLINOIS

A COLLEGE COURSE OF INORGANIC CHEMISTRY. *J. R. Partington*, M.B.E., D.Sc., Professor of Chemistry in the University of London, Queen Mary College. First Edition. Macmillan and Co., Ltd., London, 1939. x + 658 pp. 243 figs. 13.8 × 21.4 cm. $2.50.

This book represents a condensation, with considerable rearrangement and revision of subject material, of Partington's "Text-Book of Inorganic Chemistry for University Students," now in its fifth edition. The general plan and method of treatment of the larger book has been followed. In the first ten chapters an elementary introduction to the general principles of the subject is given; Chapters XI to XVI deal with oxygen, hydrogen, the halogens and their compounds. Following three chapters on electrolytes, molecular weights in solution, chemical equilibria and the law of mass action, Chapter XX discusses the Periodic Law; and the final fifteen chapters describe the chemistry of the elements according to their group positions in the Periodic Table, beginning with the alkalies and ending with the inert gases.

The history, occurrence, preparation, and properties of each element and of its compounds are presented; suitable accounts of industrial processes and of the uses of the more important substances are included. Numerical exercises are largely omitted from the book, since the author has dealt with this phase of the subject in a separate volume, entitled "Intermediate Chemical Calculations," reviewed elsewhere. An extensive set of examination questions is given as an appendix, arranged to cover the subject matter chapter by chapter, and an adequate index completes the volume.

Printed clearly on paper of good quality, with an ample supply of illustrations and diagrams, the book makes a pleasing impression upon the reader and should prove both interesting and informative to the student of freshman chemistry. While the author has succeeded in giving the modern point of view in treating such subjects as ionic equilibria, it seems regrettable that he finds it at all necessary to give two explanations of the phenomena of electrolysis of solutions of sodium chloride, sodium sulfate, copper sulfate, or barium hydroxide. The first explanation, outmoded, is given prominence, whereas the more modern interpretation is briefly presented at the end of the chapter (page 209).

The smaller compass and moderate price of the present textbook should find for it a demand in introductory courses of college chemistry which may well exceed that of the earlier, larger volume, which for years has had a popular appeal among teachers of more advanced courses in inorganic chemistry.

WALTER C. SCHUMB

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS

GENERAL COLLEGE CHEMISTRY. *J. A. Babor and A. Lehrman,* Assistant Professors of Chemistry, College of the City of New York. Thomas Y. Crowell Company, New York City, 1940. xiv + 659 pp. 151 figs. 15 × 23 cm. $3.75.

This book is a revision of the text of the same title published by Professor Babor in 1929. The authors state that the book is intended primarily for the use of students who have had a course in high-school chemistry, but that superior students without this prerequisite should have no great difficulty in understanding the text. The reviewer does not agree that the same text material can be fully satisfactory for these two different classes of students, and considers it far better to write specifically for one of these groups than to attempt to include both. The student who has had thorough preparation in an elementary school course in chemistry should be so far advanced that the material which is suited to his needs is far beyond the reasonable grasp of the beginner.

The general plan of the book is the same as that of the former edition; but it has been almost entirely rewritten in order to include new material, bring the discussion up-to-date, and provide for changes in the presentation. Little material of a purely descriptive nature, except for a review of hydrogen, oxygen, and water, is included in the first twenty-one chapters. These chapters deal with the development of the atomic-molecular hypothesis, chemical equilibrium, atomic structure, solutions, and ionization; and they are developed primarily from the theoretical point of view. Eight chapters devoted to the discussion of the non-metals and including a treatment of oxidation-reduction follow. There is next a short chapter on colloids followed by ten chapters dealing with the metals, and three, with organic substances. The usual tables and a table of logarithms are found in the appendix. A series of questions and problems is placed at the ends of the chapters.

The amount of the material included in the text is greater than can be effectively taught in a one-year college course following preparatory chemistry, and is far beyond the attainment of those who have not had this previous preparation. This is not in itself an objectionable feature, provided the material is so presented that selection can be made without loss of continuity in the development of the subject. In some instances, however, explanations are based on complex ideas which are not familiar to the student. Thus, in the discussion of atomic structure, the student encounters the terms "quanta" and "quantum theory," concepts for which he has had no adequate preparation. In other instances, it is difficult to determine the reason for the arrangement of the topics. Thus, a short paragraph discussing the abundance of the elements introduces Chapter III which deals with the atomic-molecular hypothesis.

Ideas which have not been adequately developed by the authors are frequently introduced in the discussion of important topics. Ionic equations, including the formulation of complex ions are represented as early as page 137, although the topic "Ionization" is not discussed until Chapter XIX, beginning on page 259. Again, ionic and electronic equations for reactions of oxidation-reduction, including such an equation as that for the reaction of potassium permanganate with hydrogen peroxide, are written on page 185; but the systematic discussion of this topic commences on page 341. The action of the catalyst is mentioned on pages 144 and 148; but the definition of a catalyst is on page 157. This would seem to add unnecessarily to the burden of both student and teacher.

The emphasis on industrial processes is not always well placed. From the text discussion, one would conclude that the reaction of steam with iron is the leading process for the preparation of hydrogen industrially, and that oxygen is prepared extensively from the air by the Brin process. The arc process for the fixation of nitrogen still receives undue emphasis.

In the discussion of oxidation-reduction, the authors give both the valence number and the ion-electron methods of balancing equations without attempting to show the student the advantages of each. The emphasis seems to be on the balancing of the equations rather than on the principles involved in and illustrated by the reactions. The reviewer believes that a clearer understanding of this topic may be gained through the use of the half reactions developed by the ion-electron method for all of those reactions which are primarily ionic in nature, and of the valence number method for those reactions which are essentially non-ionic.

The reviewer considers the development of ionization and the chapters dealing with ionic phenomena to be clear and well balanced. By showing the applications and limitations of the Arrhenius theory, the way is prepared for a logical presentation of the complete ionization of certain classes of electrolytes. The newer definitions of acids and bases according to the Brønsted concepts are included but are not extensively applied. These definitions, for example, are not emphasized in connection with the consideration of the common ion effect in affecting the hydrogen-ion concentration, of hydrolysis, and of amphoterism.

The descriptive chemistry of the elements and their compounds is presented from the usual point of view. The order of the arrangement of these chapters may vary, but the discussion within each group is along the conventional lines.

For those teachers who wish to develop the subject primarily from theoretical considerations, before the introduction of any considerable amount of descriptive chemistry in addition to that small body of specific knowledge which the student brings from his school course, this book should prove thoroughly satisfactory. By a complete mastery of the material in this book, the student will become well grounded in the basic principles of the subject and will be thoroughly prepared in the prerequisite material needed for advanced work in chemistry.

STUART R. BRINKLEY

YALE UNIVERSITY
NEW HAVEN, CONNECTICUT

AN INTRODUCTION TO CRYSTAL CHEMISTRY. *R. C. Evans,* University of Cambridge. The Macmillan Co., New York City, 1939. xi + 381 pp. 113 figs. 13.5 × 21.5 cm. $4.50.

Dr. Evans has taken the available data and theories on crystal structure, metallurgy, the physics of crystals, and the physical chemistry of compound formation and has woven them into a book which is so intensely chemical in its outlook that your reviewer started out to say that it was obviously written by a chemist for chemists. However, Dr. Evans is not a chemist but a mineralogist and petrologist!

The book starts out by giving the early simple pictures of the various interatomic binding forces, shows wherein these pictures were unsuitable, and then takes up the high spots of the more modern theories. The end results of these theories are set forth clearly without going into the mathematics by which they are derived. The metals are then classified for purposes of discussion into four groups: (1) the "T-group" metals, *i. e.*, the "transition metals," together with copper, silver, and gold; (2) the "A-group" metals, *i. e.*, the alkali and alkaline-earths, and beryllium and magnesium; (3) the more metallic "B_1-group" metals, *i. e.*, roughly those of the second, third, and fourth groups in the periodic table; (4) the less metallic "B_2-group" metals, *i. e.*, roughly those of the fourth, fifth, and sixth groups. The crystal structures of each of these groups are examined to see what chemical information can be gained from them, and then the various types of alloys, A-A, T-B_1, T-B_2, A-B_1, A-B_2, and B-B, are similarly discussed. Chapters follow on homopolar compounds, ionic compounds of the isodesmic, mesodesmic, and anisodesmic types, ionic compounds containing hydrogen, and molecular compounds. All this is done with a fine sense of balance between the metallurgy, physics, and chemistry which must be considered simultaneously in such a discussion.

The style of writing is simple, clear, and unambiguous. The book is remarkably free from errors. Lest anyone should think that it is too elementary, it may be said that although the book makes good and connected reading by itself, it also serves as an introduction to a bibliography which includes as much highbrow mathematics and physics as even the most fastidious could wish.

WHEELER P. DAVEY

PENNSYLVANIA STATE COLLEGE
STATE COLLEGE, PENNSYLVANIA

PHYSICO-CHEMICAL METHODS. *Joseph Reilly* and *William Norman Rae*. Third Edition. D. Van Nostrand Co., Inc., New York City, 1939. Two volumes. I, xv + 686 pp. 410 figs. II, ix + 580 pp. 437 figs. 15.5 × 24 cm. $17.50.

These two volumes, the first entitled "Measurement and Manipulation," and the second, "Practical Measurements," are a timely addition to the literature on experimental physical chemistry. Not only should they be useful to workers in physical chemistry laboratories, but also to other chemists who wish to employ physical methods.

Practically all of the material of the second edition has been retained. Most of the topics have been amplified and several new sections added. The reorganization of the topics and separation into two volumes make for efficient use whether one is interested primarily in physical chemistry or merely wishes to use it as a tool. The latter person will find the book of great value.

In Volume I some of the important additions are: chapters on measures and units, high-pressure technic; and sections on manipulation of Pyrex and quartz, hydrogenation and low temperature measurements. Volume II contains all of the practical measurements described in the second edition brought up to date and supplemented by chapters on mechanical separation, indicators, and radioactivity. Sections on electrical measurements have been considerably amplified. References to the literature contained in the section entitled "Suggestions for Further Reading" are most helpful.

The volumes are well printed and of a convenient size for use. Diagrams are profuse but in many instances could be improved. The reader should have no trouble in following descriptions of apparatus on technic. In such a work a more complete index would be preferable. With the changes the book is still of greatest value to the person interested in the methods of classical physical chemistry. There is still need for a completely modern treatise.

JOHN P. HOWE

BROWN UNIVERSITY
PROVIDENCE, RHODE ISLAND

THE LIFE OF IRA REMSEN. *Frederick H. Getman*. JOURNAL OF CHEMICAL EDUCATION, Easton, Pa., 1940. viii + 172 pp. 20 illustrations. 15.5 × 23.5 cm. $2.50

A biography of great interest to chemists and teachers has just come off the press, a book new and original both in subject and in treatment—the life story, in short, of Professor Ira Remsen, famous investigator, author, and editor, master of the art of teaching, and president of the Johns Hopkins University. The author, Professor Frederick H. Getman of Stamford, Connecticut, fortunately had access to the late Dr. Lyman C. Newell's rich store of Remseniana, to Professor E. Emmet Reid's scrapbook of personal reminiscences, to Remsen's travel diary, and to many memorabilia long treasured by the Remsen family.

With the aid of this material Dr. Getman has successfully traced the entire life story, from Ira Remsen's boyhood in the profoundly religious and sympathetic companionship of his great-grandparents (who made a place for him in their home after the death of his mother and grandparents) to the closing years when he voluntarily and happily gave up his executive responsibilities and returned to his experiments in the chemistry building.

Many of Remsen's maxims are well worth remembering:

"Be a physical chemist, an organic chemist, an analytical chemist, if you will, but above all be a *chemist*."

"The strength of an argument is inversely proportional to the amount of heat developed."

This biography is a valuable contribution to the history of chemistry in America. The many humorous quotations from the pen of Ira Remsen make it, moreover, a delightfully pleasant volume to read.

MARY ELVIRA WEEKS

UNIVERSITY OF KANSAS
LAWRENCE, KANSAS

PROPERTIES AND NUMERICAL RELATIONSHIPS OF THE COMMON ELEMENTS AND COMPOUNDS. *J. E. Belcher* and *J. C. Colbert*, Assistant Professors of Chemistry, University of Oklahoma. Third Edition. D. Appleton-Century Co., New York City, 1940. ix + 350 pp. 34 figs. 23 × 28 cm. $2.00. [*Note:* Those portions which cover the work of the first semester (Parts I, II, III, and appendix) appear also in a separate binding under the title EXPERIMENTS AND PROBLEMS FOR COLLEGE CHEMISTRY (viii + 207 pp. 17 figs. 23 × 28 cm. $1.75.)]

This rather formidable but friendly laboratory and recitation companion, which is designed to guide the student through the introductory college year of general chemistry, is based upon the Smith-Kendall series of texts. It is more than a laboratory manual; perhaps "semimicro text" would be a better term, for, in addition to detailed directions for a well-oriented series of experiments, the authors have included discussions of principles, definitions, methods of solving problems, and elaborate cross references in the texts.

Each experiment is introduced by chapter references to the texts, followed by a general discussion of the principles involved, definitions, and experimental difficulties. The directions for performing the experiment are clear and direct. At the close are pertinent problems. These direction sheets are interleaved with write-up forms, in duplicate, which consist of leading questions and spaces for observations and conclusions. The authors recommend (1) that the duplicate sheets be detached from the book and handed to the instructor at the beginning of the laboratory period; (2) that the student keep his original notes on the remaining sheets; and (3) that, at the beginning of the following laboratory period, the instructor issue duplicate sheets, to be filled out by the students under test conditions. They have found that this system not only facilitates the original write-ups, but also lessens copying and stimulates study between laboratory sessions.

Those already acquainted with the earlier editions will be pleased to know that the theory of ionization has been introduced with the first use of aqueous solutions and that ionic equations have consistently replaced molecular ones throughout. The inexperienced instructor will find the lists of apparatus and materials helpful; in their compilation of the latter, the authors have given the name of each substance, its formula, the amount required for each experiment, and the total. It is to be hoped that the authors may find it desirable to indicate the average time required to perform each experiment. Most helpful to the student are the general discussions preceding each experiment, and the final checklist of experiment subjects and references, giving experiment numbers, direction sheets and write-up sheet numbers, and chapter and page numbers in the texts.

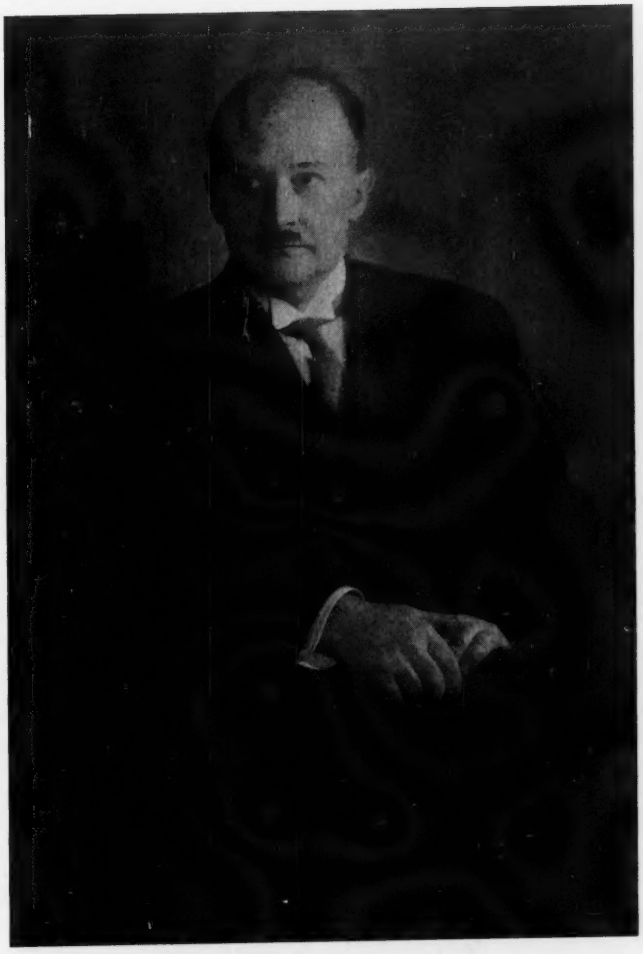
The excellent treatment of acids, bases, and salts is conservatively up to date and is followed up consistently from the introduction to the end. Altogether, the authors have produced a very attractive work which can be adapted to a wide variety of laboratory conditions.

R. A. BAKER

COLLEGE OF THE CITY OF NEW YORK
NEW YORK CITY

KINGZETT'S CHEMICAL ENCYCLOPAEDIA. *Ralph K. Strong*, Editor. Sixth Edition. D. Van Nostrand Co., Inc., New York City, 1940. x + 1088 pp. 14.5 × 23 cm. $14.00.

The sixth edition of this handbook of chemistry and its industrial applications has been strengthened on the physico-chemical side by the insertion of phase diagrams; has a new entry for pH values illustrated by a chart of indicators; contains a new article on solubilities, with tables showing solid phases and solubilities of selected important salts; has an expanded article on chemical engineering, including a consideration of materials, energy, apparatus, and economics. In addition to new items, there have been revision and expansion of articles. The makeup of the volume is pleasing, and heavy type has been used more generally and systematically in emphasizing important subheadings.



Adolf Windaus,
Göttingen.

Contributed by Ralph E. Oesper, University of Cincinnati

(For biographical sketch of Adolf Windaus, see page 499.)

« « « « « EDITOR'S OUTLOOK » » » » »

WE RECENTLY attended the Second Summer Conference of the New England Association of Chemistry Teachers and brought back (along with a refreshing breath of Maine atmosphere) several impressions, a few of which are pretty definite. Among the latter is the feeling that this is something we should have more of. Not just summer conferences, *per se*, but occasions on which high-school and college teachers can talk the same language about the same general problems.

The NEACT is perhaps the strongest, and certainly the oldest organization of its kind, and has been particularly successful in developing this sort of accord. Too often, high-school teachers feel inferior, and college instructors bored, when they get into each other's professional company.

The collegiate group are busy tending the *flowers* of the chemical education plant and are often unconscious of what is taking place down in the *roots*. And educational developments often have a way of starting at the bottom and spreading upward. The "project method" and the "survey course," for example, started in the roots and spread to the branches.

And now this vague movement of what probably must be called "socialized science" is creeping up. It has scarcely penetrated to the flowering parts of the plant yet, but if you happen to regard this advance as a diseased one, and if you have been spending all your time in the upper limbs, don't be surprised if they break off behind you sometime.

Teacher circles seem to divide themselves into two diametrical segments on the appearance of this issue. The argument runs something like this: Education is for *life* and its value is the measure of its application to life's problems. From this standpoint there is no sense to the present "compartmentalized" curriculum. Subject matter should be arranged in patterns according to its application to the problems of modern social living, with no reference to the traditional boundaries of the individual sciences. "Consumer chemistry," about which we have been hearing a good deal, is one small angle of this larger movement.

Probably we don't disagree very fundamentally as to the desirable ends of education, but we can get into some fine arguments over the means. Many of us are not going to like the idea of dropping "chemistry," "physics," "mathematics" from our curricular vocabulary, in favor of such items as "transportation," "housing," "health," "clothing," "weather," "entertainment," etc.

None of the subject-matter groups is perhaps as well organized as that in chemistry, but while we have been busy talking shop with each other things have been going on around us, whether we like it or not. Our educational curricula are being shaped by men who have not been looking at the educational process from the standpoint of subject matter—certainly not chemistry in particular. Some of them haven't even been trained in subject matter. This movement seems destined to continue, and if teachers of chemistry are not content to see chemistry lose its identity in the curriculum—at least in the secondary school—they had better get vocal on the matter.

And there is certainly something to get vocal about. We can admit that something should be done to make chemistry more vital and useful to the student who gets no more than one general course, but it is scarcely necessary to go to the length of submerging the individual natural sciences. Nevertheless, the possibility of this seems to have caused an air of pessimism in the minds of some teachers who complain that the long-dominant physical sciences are giving way rapidly to the social studies. At the risk of being called "appeaser" we prophesy that the solution will be a compromise. Chemists haven't been too well prepared for this attack, and there have been some weak points in their defenses, anyway.

The vested interest which chemistry has had, and still has, in the educational curriculum is considerable, but our standpoint is hardly that of the economic royalist. We, too, are concerned with the greatest good to the greatest number.

As the Educational Policies Commission, one of the strongholds of the educationists, puts it, the avowed purpose is "To improve the effectiveness with which American schools develop in young people an intelligent, appreciative, and active loyalty to democracy."

Chemical education has no quarrel with this; in fact it expects to fulfil its part in carrying out such a program. Here is a challenge to all teachers of chemistry to show that what they have to offer contributes to that end. Let them show the real impact of chemistry —and especially the appreciation of the scientific method and science in general—upon modern life.

Political democracy presupposes a public intelligent on the principles upon which its government is based. These involve economic factors, which in turn involve the scientific aspects of the economics of production. The next step may perhaps be industrial democracy, and to be eligible for this the public must be vastly more intelligent upon the fundamentals of industrial production than now. And that means more, not less, education on the relation of science to industry.

LETTERS

Teaching Chemistry with Blackboard Diagrams

To the Editor:

Verbal discourse, which is the most common method of teaching, when combined with a visual form is more surely effective than either used separately. Theoretical treatments which do not lend themselves to actual demonstration, as well as many experimental procedures, can best be visualized by the student from drawings on the blackboard or supplementary sheet. A more lasting impression will be conveyed by a drawing which is carefully explained than can be given by words alone.

Schematic diagrams tend to develop clear mental images by forcibly concentrating attention on facts, details, and ideas of a theoretical nature. Simple, labeled drawings are easily understood and remembered. The movement of gases, liquids, and solids can be indicated by directional arrows. Colored chalk can be used to emphasize various aspects of the diagram, focusing the attention of the student on the principle involved.

Since chemistry is the science which treats of material transformations, the ideal classroom presentation would seem to be one in which the student can see these changes with the naked eye. Where this is not possible or practicable, the principles of chemistry should be exemplified so that the student establishes concepts of processes such as: solution, burning, absorption, evaporation, and condensation; and can visualize substances which have crystalline shape, density, weight, volume, and color. The use of blackboard diagrams accomplishes this objective.

LEONARD A. FORD

STATE TEACHERS COLLEGE
MANKATO, MINNESOTA

High-School Chemistry Courses

To the Editor:

For many years now, high-school courses labeled "chemistry" have been becoming more interesting, fascinating, and popular—and more useless. High-school chemistry is now, to a great extent, a "recreational" (to use a prominent educator's suggestion) rather than a "vocational" subject. Potentially brilliant chemistry "majors" come to think of chemistry as a grand lark—a continuous succession of intriguing tricks of magic. They get no conception of the subject as a hard, solid, practical science. When they come to college, delightedly planning to "major" in this fascinating branch of knowledge, and discover that they are required actually to learn dry subject matter—symbols, formulas, laws, and principles—to figure out numberless equations, work problems requiring a rudimentary knowledge of the multiplication table (which they have long since forgotten), and patiently carry out tedious, accurate, quantitative analytical determinations, they are apt to lose interest.

It can hardly be too strongly emphasized that the recent totalitarian success is due chiefly to superb technic—extending from army commanders and industrial Führer right down through all ranks of men to the common soldier and the humblest munitions-worker. It is a technic embracing war, industrial, economic, and civil administration, education, sanitation—every aspect of the life of the nation. While we cannot approve of its objectives, we must admire its ruthless competence and effectiveness.

"Progressive" education has softened the fiber of American youth. They no longer have any concept of the necessity of accomplishment and achievement through tedious drudgery and desperate, determined striving. Education has become a right, rather than a precious privilege, for which no effort and no sacrifice should be too high a price to pay.

Chemistry is the most widely applied of the practical sciences. "Total" war demands the services of enormous numbers of highly trained chemists. High-school chemistry teachers, more than any others at the secondary level, have it within their power to train our youth adequately for the coming struggle, not only by giving sound instruction in technical chemistry, but by inculcating habits of diligence, concentration, accuracy, and manipulative skill; and also by insisting upon adequate grounding in those tool-subjects which are the essential foundation for competence at higher levels.

G. WAKEHAM

UNIVERSITY OF COLORADO
BOULDER, COLORADO

Enough Is Enough

To the Editor:

During several years of devotion to the JOURNAL OF CHEMICAL EDUCATION I have been, in turn, gratified, interested, impressed, astonished, and amused by the activity of the unofficial Committee on Ways and Means of Balancing Oxidation-Reduction Equations. I am now looking forward to my next feelings on the matter.

At present, I have at my disposal eight volumes and thirteen miscellaneous numbers of the JOURNAL OF CHEMICAL EDUCATION, and in these there appear no fewer than thirty assorted articles, notes, communications, and other offerings on the topic.

Is this topic worthy of such fluent discussion? More than one of my students, when referred for his own in-

terest to some of the various methods which have been suggested by contributors to this JOURNAL, have returned to ask me if the ability to balance equations of oxidation and reduction is the criterion by which a chemist is judged. I believe that I gained a similar impression as an undergraduate student. And there was a period in my teaching when I spent a disproportionate amount of time in general chemistry in trying to get all my students to learn to balance such equations as:

$$10Pb_3O_4 + As_4 + 30H_2SO_4 \rightarrow 30PbSO_4 + 4H_3AsO_4 + 24H_2O$$

But I have learned that there are some members of a beginning class who never can (or never will) learn to balance an equation more complicated than the simplest metathesis.

I have no wish to minimize the importance of a correctly balanced equation, or accuracy and completeness in a student's work. But it has been my observation that any student, especially any chemistry "major," worthy of the name quickly grasps the idea of balancing an equation for a reaction in which a transfer of electrons is said to take place. After all, it is nothing but a simple mathematical exercise, and I feel that a deluge of details such as that described by Barthauer (February number of the JOURNAL) and discussed by various writers (August number) serves only to tend to obscure the chemical principles involved. I know some teachers, and I suspect that there may be many others, who share my point of view.

JAMES B. SCHROYER

ADRIAN COLLEGE
ADRIAN, MICHIGAN

Benjamin Rush to William Cullen

To the Editor:

In the first volume of the "Life" of Dr. William Cullen[1] there is printed, *circ.* page 650, a letter that was sent to Cullen from Philadelphia by Dr. Benjamin Rush, who had been under instruction by him in the University of Edinburgh as a student of medicine.

During the examination of a collection of Cullen manuscript material that is preserved in the Library of the University of Glasgow, an earlier letter from Dr. Rush to Dr. Cullen was met with, and this, by the courtesy of Dr. W. R. Cunningham, The University Librarian, I am permitted to publish. Your JOURNAL appears to be a fitting place for its publication. Accordingly I have pleasure in now placing at your disposal the accompanying copy of it for that purpose.

LEONARD DOBBIN

GAVELTON, FALADAM
BLACKSHIELS, SCOTLAND

Philad[a] Sep. 16th 1783.

MY DEAR FRIEND,

Your letter by Mr. Todd made me very happy, but did not (because it could not) add to my sense of obligations and friendship to you .... The events of the late war have not lessened my attachment to my venerable master.... The members of the republic of science all belong to the same family. What has physic to do with taxation or independence?

One of the severest taxes paid by our profession during the war was occasioned by the want of a regular supply of books from Europe, by which means we are eight years behind you in everything. Your First Lines was almost the only new book that was smuggled into the country. Fortunately it fell into my hands. I took the liberty of writing a preface to it, and of publishing it during the war.... The American edition had a rapid sale and a general circulation throughout the United States. It was read with peculiar attention by the physicians and surgeons of our army, and in a few years regulated in many things the practice of our Hospitals.... Thus, Sir, you see you have had a hand in the revolution by contributing indirectly to save the lives of the Officers and Soldiers of the American Army.

Mr. Todd cannot fail of doing well in our country. He will have his choice of two or three public schools, each of which will be worth not less than £150″0″0 sterling a year to him.

The Practice of Physic still continues to be laborious and by no means profitable in proportion to our labour in this new country. The professions of physic—Surgery and Pharmacy are still blended together. Our medical school has declined during the war, but we expect will revive with the peace.... The crowds of strangers which our commerce has invited to our city, together with some other circumstances have rendered the present season extremely sickly. The Scarlatina has been epidemic amongst us. Your treatise upon this disorder has been my guide in all the cases that come under my care.

I cannot conclude this letter without repeating my obligations to you for the friendship I experienced, and the instruction I derived from you, while in Edin[r]. If I have added anything to my stock of ideas since I left you .... If I have been a patient .... observer of nature .... and a faithful compiler of facts .... If I have been in any degree useful or successful in my profession .... I owe all these things to you .... May you live long .... very long to enjoy such effusions of gratitude from your pupils, and continue every year to bless the world with your invaluable works.

With most respectful Comp[ts] to your family,
I am D[r] Sir. Your
Most affectionate pupil
and obliged friend &
H[ble] Servant

BENJ[N] RUSH.

[1] THOMSON, "An account of the life, lectures, and writings of William Cullen, M.D.," Edinburgh and London, 1832.

The MCM Solution

To the Editor:

It is well known that aqueous molal solutions contain one gram molecular weight (one mol) of solute in 1000 grams of water. Since the molecular weight of water is 18, a molal solution contains one mol of solute in 1000 ÷ 18, or 55.5 mols of water.

A more convenient unit would contain one mol of solute in 1800 grams of water, *i. e.*, in 100 mols of water. This might be called a mol-in-100-mols, or MCM, solution.

Since lowering of vapor pressure, lowering of freezing point, and rise in boiling point are governed by the mol-fraction rule, the MCM system would not only simplify calculations, but would also promote mol-fraction consciousness.

And, finally, it would eliminate the confusion which is always apt to exist between molar and molal solutions.

E. A. VUILLEUMIER

DICKINSON COLLEGE
CARLISLE, PENNSYLVANIA

HENRY CARRINGTON BOLTON

Historian and Bibliographer of Chemistry[1]

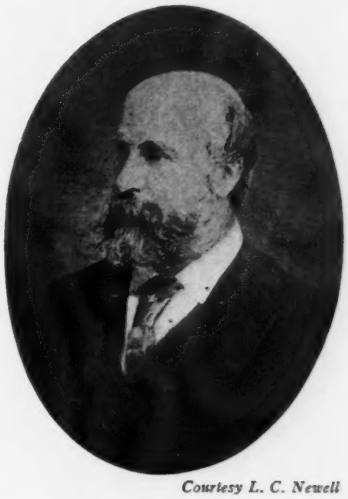
C. A. BROWNE

Bureau of Agricultural Chemistry and Engineering, United States Department of Agriculture, Washington, D. C.

THE present paper is a short tribute to a distinguished American chemist of two generations ago, who as a scholar, historian, and bibliographer of chemistry will always hold a high seat of honor among the scientists of the world. He is Henry Carrington Bolton, who is also to be remembered as one of the organizers and founders of the American Chemical Society (*1*).

He was born on January 28, 1843, in the downtown section of New York City at 58 Greenwich Street near the Battery. His father and maternal grandfather were physicians, and the traits for science and scholarship which Bolton exhibited throughout his life were no doubt inherited from both paternal and maternal lines. His first instruction in chemistry was obtained under Professor C. A. Joy at Columbia University, from which he graduated in 1862 at the early age of nineteen. Immediately after graduation he went with his parents to Europe, where he continued his chemical studies in Paris, first under Dumas at the Sorbonne and then in the laboratory of the École de Médecine under Wurtz. In 1863 he proceeded to Heidelberg in Germany where he worked in the University laboratory under Bunsen and heard the lectures of Kirchhoff and Kopp. It was probably under Kopp, the distinguished German historian of chemistry, that Bolton's interest in this subject was first awakened. He then spent a summer semester at Göttingen with Wöhler, under whom a research was begun on uranium. This investigation, on Wöhler's advice, was then continued for several semesters in the private laboratory of Hoffmann at Berlin. Bolton then returned to Göttingen where in 1866 he took his Ph.D. degree with a thesis, "On the Fluorine Compounds of Uranium." This inaugural dissertation was published at Berlin in English. It was through his work on uranium that Bolton prepared an index of the literature of this element, which was published in 1870 in the Annals of the New York Lyceum of Natural History. This was Bolton's first entrance into the field of bibliography in which he was later to win such great distinction.

In the vacation periods of his five years of foreign study, Bolton spent much time in travel and thus laid the foundations of this deep knowledge of the history, folklore, languages, and culture of the different European countries. After his return to America he conducted a private research laboratory in New York for several years, and then in 1872 accepted a position as assistant in analytical chemistry at the Columbia College School of Mines. Bolton's first contributions to the history of chemistry date from this period. His paper, "Historical Notes on the Defunct Elements," is the opening article of Vol. I (July, 1870) of Chandler's *American Chemist*. Among other contributions in this journal is his "Views of the Founders of the Atomic Philosophy" in the issue for March, 1873. His series of "Notes on the Early Literature of Chemistry," published in various issues of the *American Chemist* between 1873 and 1879, consisted of seven papers and are highly important. The first of these, published in November, 1873, shows that Bolton had already laid the foundations of his future work in the fields of chemical history and bibliography. He remarks in his introduction to the series:



Courtesy L. C. Newell

HENRY CARRINGTON BOLTON

"These observations appear to deserve publicity and may, to some extent, prove contributions to the History of Chemistry. References will be fully given and the bibliography of chemistry will receive special attention."

Bolton's bibliographic plans were outlined more specifically in the third article of this series in the *American Chemist* for January, 1874, which contains specimen descriptions of 56 different works, with annotations that are identical with those in his large bibliography published in 1893. This gigantic work is

[1] Presented before the Division of the History of Chemistry at the ninety-ninth meeting of the A. C. S., Cincinnati, Ohio, April 9, 1940.

thus seen to be the result of at least 20 years of careful preparation.

Bolton's early historical studies took a more practical turn in April, 1874, when he published a note in the *American Chemist* (Vol. IV, p. 362), suggesting that American chemists celebrate the centennial of Priestley's discovery of oxygen on the following August 1. The proposal received a most favorable response and resulted in a meeting of 77 chemists at the home of Priestley in Northumberland, Pa. A prominent feature of this meeting was Benjamin Silliman, Jr.'s address on "American Contributions to Chemistry," which marked the beginning of all future work on the history of chemistry in America. An important outgrowth of this Northumberland meeting of chemists was the founding of the American Chemical Society in New York on April 6, 1876, Bolton being among the organizers and charter members.

LABORATORY WHERE H. C. BOLTON TAUGHT QUANTITATIVE ANALYSIS AT THE COLUMBIA COLLEGE SCHOOL OF MINES, NEW YORK CITY, IN 1873

The Northumberland Centennial brought Bolton into close relationships with many of Priestley's descendants, who showed him their collections of ancestral relics. It is from this time that we can date the beginning of Bolton's interest in Priestley. He delved into the study of his life from every angle, the results of his investigations being privately published in 1892 as a valuable work of 240 pages under the title, "The Scientific Correspondence of Joseph Priestley." This book contains not only a reproduction of 97 of Priestley's scientific letters but a 22-page contribution on "The Likenesses of Priestley in Oil, Ink, Marble and Metal," in which 93 different portraits, medallions, caricatures, busts, statues, etc., of Priestley are described. The volume includes also an interesting account of "The Lunar Society of Birmingham" and an inventory of Priestley's apparatus that was destroyed in the Birmingham riots of 1791.

During the five years of his instructorship at the Columbia School of Mines, Bolton published numerous articles in the *American Chemist* on schemes of qualitative analysis, chemical apparatus and other related subjects, besides making translations and abstracts of foreign literature. He also published several pieces of original research on the ores and compounds of uranium and a collaborative investigation with President Henry Morton of Stevens Institute of Technology on "Fluorescent and Absorption Spectra of Uranium Salts."

In 1875 Bolton resigned his appointment at Columbia to become professor of chemistry at the Woman's Medical College of the New York Infirmary, a position which he vacated in 1877 in order to accept the professorship of chemistry at Trinity College, Hartford, Conn., where he taught for the next ten years. During this period he published his "Students' Guide in Quantitative Analysis" (New York City, 1882), which was extensively used fifty years ago and passed through three editions.

Having ample private means, Bolton withdrew from teaching in 1887 in order to devote the remainder of his life to his favorite pursuit, the history and bibliography of chemistry—subjects in which he had already won distinction as the leading American authority. In his address on "Chemical Literature" at the Montreal meeting of the American Association for the Advancement of Science in 1882, Bolton suggested the formation of a committee on indexing chemical publications. As chairman of this committee he prepared ten annual reports to the association, and at the same time finished the compilation of several large volumes of useful scientific works of reference. The first of these was his "Catalogue of Scientific and Technical Periodicals, 1665–1882," published as Vol. XXIX of the Smithsonian *Miscellaneous Collections* in 1885. A second edition of this work with chronological tables and library check list, a book of 1247 pages, was published by the Smithsonian Institution in 1897. The second edition of the catalog covers the period 1665–1892, and includes 8603 entries of periodicals in various languages under 102 different subjects. The library check list attached to this catalog was the outcome of an attempt to determine in what American libraries the periodicals listed in the volume could be found.

Bolton's famous "Select Bibliography of Chemistry, 1492–1892" was published by the Smithsonian Institution in 1893. This work, which might be considered as a contribution of American science to the celebration of the 400th anniversary of the discovery of America, is a volume of 1212 pages, and for convenience of reference is divided into seven sections of publications on (1) bibliography; (2) dictionaries; (3) history; (4) biography; (5) chemistry, pure and applied; (6) alchemy; and (7) periodicals. Some idea of the stupendous labor involved in this work can be formed from the fact that in its preparation Bolton made visits to many large libraries of Europe and that a large staff of linguistic experts were engaged to assist in the work of compilation. A total number of 12,031 works in 25 different languages were listed; the proofreading alone occupied a period of twelve months. A first supplement of this Bibliography, with the listing of 5554 additional works, published in 1899, brought the literature down to the close of the year 1897, and a second supplement, published in 1904, continued the compilation to the close of 1902. Included in this Bibliography of Chemistry is another supplementary volume of 534 pages of "Titles of Academic Dissertations" which was published by the Smithsonian in 1901. The "Catalogue of Scientific and Technical Periodicals" and the four volumes of Bibliographies will always stand as an enduring monument of Dr. Bolton's scholarship and industry. As Dr. F. W. Clarke remarked in his obituary of Bolton, "Had he done nothing else, he would still be entitled to the gratitude of chemists for all time."

But this does not represent the sum total of Dr. Bolton's contributions to the literature of chemistry and science. A list of all his minor contributions to different phases of the history of chemistry and science would exceed the limits of the present contribution. In the Library of Congress are 81 card references to his various publications. Here also are four large scrapbooks of what Bolton terms "Pamphlets and Fugitive Pieces," carefully arranged chronologically in his neat, methodical manner. These consist of reprints and clippings of a multitude of articles which he dashed off from time to time in the intervals of his other work. His pen seems never to have been idle.

We have already mentioned several of Bolton's early historical chemical contributions that appeared in Chandler's *American Chemist*. Of other miscellaneous contributions of this character may be mentioned his articles on the "Ebers Papyrus" in the *London Quarterly Journal of Science* for 1876; on "Ancient Methods of Filtration" in the *Popular Science Monthly* for 1879; on the "History of Chemical Notation" (two papers) in the *Transactions* of the New York Academy of Sciences, 1883; on "The Contributions of Alchemy to Numismatics" in the *American Journal of Numismatics* for 1890; on "The Progress of Chemistry as Depicted in Apparatus and Laboratories" in the *Transactions* of the New York Academy for 1893; on "Early American Chemical Societies," read before the Washington Chemical Society and published in the *Journal of the American Chemical Society* for August, 1897; on "The Revival of Alchemy" read before the New York Section of the American Chemical Society and published in *Science* for December 10, 1897; on "The Evolution of the Thermometer, 1592–1743," a small illustrated book of 98 pages published at Easton, Pa., in 1900; and on "Chemical Societies of the Nineteenth Century" in the *Miscellaneous Publications* of the Smithsonian Institution for 1902. The mention of his numerous short notes and fugitive pieces, dealing with Chinese alchemy, sulfur matches, and other subjects, must be passed over.

In addition to these works dealing with the history of chemistry, Bolton was the author of a large number of miscellaneous literary and scientific papers on such subjects as "Magic Squares," "Legends of Sepulchral and Perpetual Lamps," "Historical Notes on the Gold Cure," and "Counting-out Rhymes for Children; their Antiquity, Origin and Distribution." The work on "Counting-out Rhymes," published in 1888, was a study in folklore that won for the author a medal at the Columbian Historical Exposition of Madrid in 1892. Other contributions in this field, published in the *Journal of American Folk-Lore*, were his papers on "Some Hawaiian Pastimes" (1891); "A Modern Oracle and Its Prototypes" (1893), which was a study in catoptromancy, or divination with mirrors; and "Fortune Telling in America Today" (1895). For his work in folklore, Bolton in 1893 was elected the first president of the New York City branch of the American Folk-Lore Society. Also related to folklore was Bolton's paper on the "Language Used in Talking to Domestic Animals," published in the *American Anthropologist* for 1897.

A unique scientific subject to which Bolton gave much attention was musical sand, by which is meant the property that the sand of certain beaches and dunes has of emitting a musical note when trodden under foot or otherwise rubbed. In search of sands having this property, he made journeys aggregating 33,000 miles. His contributions (*2*) on this subject, in conjunction with Dr. A. A. Julien, attracted wide attention.

Genealogy was another field in which Bolton delved rather deeply. In 1887 he published a paper on "The Life and Writings of Elisha North, M.D.," who was his maternal grandfather, and in 1895, in association with his cousin, Reginal Pelham Bolton, he published "The Family of Bolton in England and America, 1100–1894."

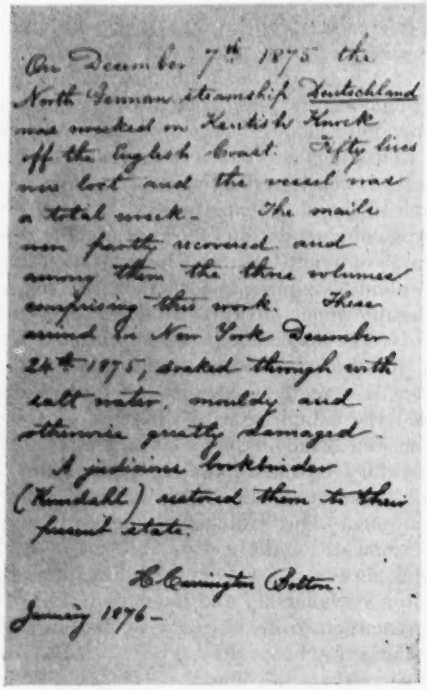
THE FAMILY COAT OF ARMS, USED ON THE BOOKPLATE OF H. C. BOLTON

In the month previous to his death, Bolton published the nineteenth and final chapter of his "Follies of Science in the Court of Rudolph II," the successive installments of which had appeared in the monthly issues of the *Pharmaceutical Review*, extending from April, 1902 to October, 1903. These chapters were assembled and published in book form in 1904 by the Pharmaceutical Review Publishing Company of Milwaukee. It is a work of 217 pages, beautifully illustrated with pictures of historic sites and personages, with reproductions of alchemistic paintings and curious emblems, and with attractive initials and tailpieces. In many respects it is the most fascinating book of Bolton's and exemplifies to the fullest degree his encyclopedic knowledge of curious lore and his great charm of presentation. We wonder at Bolton's power of simultaneously carrying on so many different literary undertakings. The second supplement of his "Bibliography" and his "Follies of Science" appeared in book form almost at the same time, just after his death at the early age of 60 years. He was denied the privilege of holding in his hands these last productions of his tireless energy.

We cannot speak further about Bolton's literary productions, on which much more might be said, but must say a few words in conclusion about his work as a collector and bibliophile. His collection of rare books on alchemy and chemistry was one of the finest in the United States, and after her husband's death it was given by Mrs. Bolton to the Library of Congress.

In his large Bibliography of Chemistry, Bolton marked the books in his private library with an asterisk. These number 606, of which 241 were works on alchemy, 131 on pure and applied chemistry, 129 on the history of chemistry, 87 on biography of chemists; 17 were dictionaries of chemistry, and one was a bibliography. His collection on the history of chemistry extends from the early Latin work of Borrichius on "The Origin and Progress of Chemistry," of the year 1668, down to 1892. Many of the entries are accompanied by valuable explanatory annotations which are indicative of Bolton's great erudition and critical judgment He is particularly severe in his condemnation of the national bias and inaccuracy of many of the French historical writers as Dumas, Bechamp, Cuvier, Gautier, and others. He owned all the historical works of Kopp, whose "History of Chemistry" he characterizes as "a classical work, above praise."

In addition to these annotations in the Bibliography, the penned inscriptions of Bolton on the flyleaves of his books, giving facts about his acquisition of particular works and other incidental information, are of great interest. We cannot go into the story of these inscriptions but the accompanying photograph of an annota-



On December 7th 1875 the North German steamship Deutschland was wrecked on Kentish Knock off the English coast. Fifty lives were lost and the vessel was a total wreck. The mails were partly recovered and among them the three volumes comprising this work. These arrived in New York December 24th 1875, soaked through with salt water, mouldy and otherwise greatly damaged. A judicious bookbinder (Rundell) restored them to their present state.

H. Carrington Bolton.

January 1876.

NOTATION BY H. C. BOLTON ON THE FLYLEAF OF VOLUME I OF HIS SET OF GMELIN'S "GESCHICHTE DER CHEMIE"

tion on the flyleaf of the first volume of his set of Gmelin's "Geschichte der Chemie" is indicative of their nature and also of Bolton's beautiful handwriting, clear-cut as the impression of a copper plate.

Bolton was also a collector of engravings of famous chemists and other scientists. He made a selection of these for making his extra-illustrated set of Poggendorff's "Biographical Dictionary of Scientists (1863–1898)," the print of each scientist being inserted opposite the page of his biographical sketch and the various volumes (expanded from three to six) being then rebound. The result was a set of Poggendorff of almost priceless value, of which it can truly be said there is not a duplicate of it in any part of the world. It now forms a part of the Bolton collection in the Library of Congress.

Physically, Dr. Bolton was a man of medium height, of somewhat stocky frame and with light blue eyes. He was quite bald and wore a beard which in early manhood was black but later became tinged with gray. He was a man of amiable disposition and of a deeply religious nature.

In October, 1893, Dr. Bolton married Miss Henrietta Irving, a grandniece of Washington Irving, and after a year of travel he and his wife made their home on K Street in Washington, where the large Government libraries afforded unequaled opportunities for bibliographic and historical research. His refined and attractive home became a social center of Washington scientific circles, and here he labored until his untimely death on November 19, 1903. Bolton was then at the height of his creative powers and, had his life been spared, the literary and historical phases of chemistry would have been still further enriched.

Dr. Bolton was a prominent member of many scientific associations, and at the time of his death was said to belong to more learned societies than any other American. He was an ex-president and patron of the New York Academy of Sciences, a charter member of the American Chemical Society, a vice-president (Section C) of the American Association for the Advancement of Science, an ex-president of the District of Columbia Library Association, and an ex-president of the Washington Chemical Society, to name only a few of the organizations with which he was connected. In all these societies he made a host of friends, who spoke with admiration of his geniality, culture, and kindly spirit. In the words of his friend, Dr. F. W. Clarke, he was "a man who was universally beloved. Higher praise than this cannot be given to any man."

LITERATURE CITED

(1) Sketches of Henry Carrington Bolton are found in the "Dictionary of American biography" (**2**, 422–3), in the "Proceedings of the Am. Chem. Soc.," **1904**, p. 6, and in the *Popular Science Monthly*, **43**, 688–95 (1893).
(2) Researches on "Musical sand in the Hawaiian Islands" and in *California Trans. N. Y. Acad. Sci.*, Oct. 27, 1890, pp. 28–35.

LABORATORY SYNTHESIS OF ETHYL CHLORIDE

I. A. KOTEN

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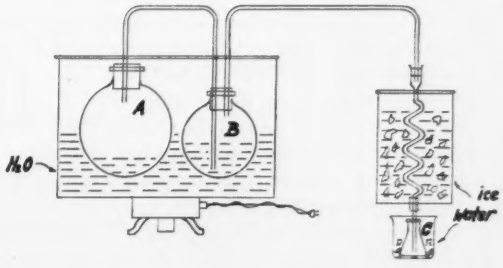
THE following procedure is suggested as being rapid and convenient for the laboratory or lecture preparation of ethyl chloride:

Into a 500-ml. flask (*A*) place 150 ml. of 95 per cent alcohol and 25 g. of anhydrous calcium chloride. Shake the mixture until practically all of the calcium chloride is dissolved, and then add 35 g. of ethyl sulfate (E. K. Practical). Place the flask on the water bath and connect with the 250-ml. flask (*B*), which contains 75 ml. of concentrated H_2SO_4. Connect with the condenser immersed in a freezing mixture of salt and ice. The liquefied ethyl chloride drops into the receiving flask (*C*), which is also packed in a cooling mixture. The temperature of the freezing mixture should be about −10°C. After the flasks have been securely connected the temperature of the water bath is gradually raised to 70°C. and kept there for the duration of the preparation, which is usually about half an hour. Upon warming the mixture in flask *A* copious evolution of ethyl chloride begins. The compound in its gaseous state is bubbled through concentrated H_2SO_4 in order to free it from alcohol vapors and moisture. After the reaction is completed the secondary product appears as a precipitate. The ethyl chloride thus obtained is always of interest to students, who note the extreme cooling effect produced upon pouring this compound over the back of the hand.



The yield of pure ethyl chloride based on the calcium chloride used according to the reaction:

$$CaCl_2 + (C_2H_5)_2SO_4 \rightarrow C_2H_5SO_4CaCl + C_2H_5Cl$$

averages 63 per cent. One ethyl radical of diethyl sulfate reacts more vigorously than the other.[1]

[1] CADE, A., "Commercial ethylation with diethyl sulfate," *Chem. and Met. Eng.*, **29**, 319 (1923).

PREPARATION *of* LANTERN SLIDES *without a* CAMERA[1]

L. A. GOLDBLATT[2] AND JAMES E. BATES

Erie Center, University of Pittsburgh, Erie, Pennsylvania

IN this paper, emphasis has been placed upon the more convenient methods of preparing homemade slides, using the materials and equipment most commonly available.

Probably the simplest slide to make is the ground glass slide. Ground glass can be inscribed with ordinary lead pencil or crayon,[3] may be erased or washed with soap and water and used repeatedly if desired. A very coarse form of ground glass can be purchased from almost any glazier. Such glass is sold by the square foot, and as the price is usually the same whether bought in large or small pieces, it is advantageous to purchase glass plates the size of the standard American slide, $3\frac{1}{4}'' \times 4''$. Use of a finer grade of ground glass, the so-called satin finish ground glass which is usually obtainable at the larger window glass supply houses or dealers in photographic supplies, permits finer lines and shading. The edges of such cut glass plates should be smoothed off or taped, for comfortable handling.

Plain glass can be written on with India ink but the ink tends to crack or check with age. A homemade ink that writes reasonably well on glass can be prepared by dissolving three per cent of celluloid (or nitrate base photographic film) in methyl cellosolve and adding a suitable dye, *e. g.*, malachite green. Plain glass can be colored very nicely with such lacquers. The suggestion has been made that plain glass can be coated with gelatin or lacquer and that such a coating will take ink better than plain glass itself, but there would seem to be easier ways of making glass slides. One is the use of old photographic slides from which the silver has been bleached out with dichromate leaving a clear, gelatin coated, glass slide. Commercial glass-marking inks are available and can be used to write directly on clear glass with an ordinary steel pen. Such writing is quite permanent and can be washed off only with considerable difficulty. The suggestion has also been made that for temporary use glass can be smoked over with a smoky flame and inscribed by means of a pencil or match stick. Such a slide can be used repeatedly, as when projecting election returns.

Thin sheets of transparent celluloid, cellulose acetate, ethofoil, etc., can be used instead of glass and can be inscribed with suitable inks.[4] Such transparent sheeting can be inserted in a typewriter and typed directly or through carbon papers. Sharp impressions can be obtained by placing the piece of transparent sheeting inside a piece of carbon paper folded with the coated surfaces inside and typing with a displaced ribbon, as when cutting a stencil. Sheeting about 0.012″ in thickness is usually stiff enough to remain upright unsupported in a projector, yet thin enough so that it can be typed conveniently. Such sheeting can be obtained directly from the manufacturers or from many stationery, hardware, or automobile supply stores and can easily be cut into $3\frac{1}{4}'' \times 4''$ (slide size) pieces.[5]

Inscriptions can be wiped off quite easily with a dry rag and the same blank plate can be used repeatedly. Of course this means that such slides will smudge rather easily also. If a permanent slide is desired, such writing should be protected by cover glasses. However, in that case it is probably preferable to use a thinner transparent sheeting such as cellophane or pliofilm. Such thin foil can be inscribed with ink or typed between carbon papers exactly like the heavier sheeting.[6] One can cut one's own 5- and 10-cent store cellophane to lantern slide size, or cellophane sheets already cut to size may be purchased for as little as 500 sheets for a dollar. Commercial forms of such cellophane blanks previously fitted with mask and carbons and ready for typing can be purchased for from two to three cents each. Several shades are

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[5] Several persons have inquired whether a celluloid slide will not become overheated if it is allowed to remain in the projector too long. Pyralin slides have been allowed to remain exposed in a projector (Delineascope Model D, 500 watts, manufactured by the Spencer Lens Company of Buffalo, N. Y.) for as long as half an hour without any detectable change except, perhaps, for a slight discoloration.

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FIGURE 1.—REFLECTION METHOD OF PHOTOGRAPHIC REPRODUCTION

available. Amber is said to be easier on the eyes of the spectator. Such thin films will not remain upright unsupported in a projector, but may be sandwiched between two plain cover glasses, hinged with adhesive paper or scotch tape.

A finished binding may be obtained by using adhesive paper or scotch tape. To make such a permanent binding, cut off a 15-inch length, place this flat on a table, and holding the two cover glasses firmly together, place one edge in the middle of the binder and rotate the slide along the tape, keeping the edges in the middle of the tape. Crease the tape down over the edges of the glasses, reserving the corners until the last. A simpler binding, sufficient for all ordinary circumstances, is made by simply fixing two short pieces of tape to a slide, one on either end. It is customary to place a tab on the front, upper right corner of the slide as it will be placed in the projector. Such a marker (suitably a punching from a piece of gummed paper) should be placed on the lower left corner of the slide when it is held in a position to be read normally.

There exists an apparently almost uncontrollable tendency on the part of exhibitors to attempt to put too much material on a single slide. The whole area of a slide cannot be projected and ample margins should be allowed. Nor should there be too much crowding in the center or the legend will not be legible. If pica type is used, not more than fifteen lines of thirty spaces each should be used on a single slide; if élite type is used, as many as sixteen lines of thirty-eight spaces each may be used. There is little danger of overcrowding a typed slide because even if élite type is used, the projected image should be legible if on a fairly large screen. A good working rule is this: No character on the screen should be smaller than one five-hundredth of the distance to the most distant spectator.

Material which is already available in black and white, as in a book or typed page, can be very readily copied photographically. Two classes of such material may be distinguished: first, that in which the copy is not as large as a standard slide and, second, that in which the copy is larger than a slide. In the first case, two situations may be treated separately; first, if the material is printed on only one side of the page, and, second, if both sides are printed.

In the first case, where the material to be copied is not as large as a standard slide and is printed on only one side, the extremely simple method of *transmission* can be used. In this case, a paper negative is made by passing light through the printed page onto a piece of photographic paper. This is developed and then printed onto a film or photographic slide to make a positive transparency. Thus, in one specific case, a paper negative was made using Velox F-5 paper. The sensitized paper was placed emulsion side up and the material to be copied placed in contact with the emulsion. These were pressed together tightly with a heavily weighted piece of plate glass. *Intimate contact between the paper and the material to be copied is essential.* The upper blank surface of the page to be copied was then illuminated with a type A Photoflood bulb held in a desk lamp at a distance of two feet. (The light therefore passed through the glass plate, then through the blank side of the page, then through the printed side of the page, finally striking the sensitized emulsion

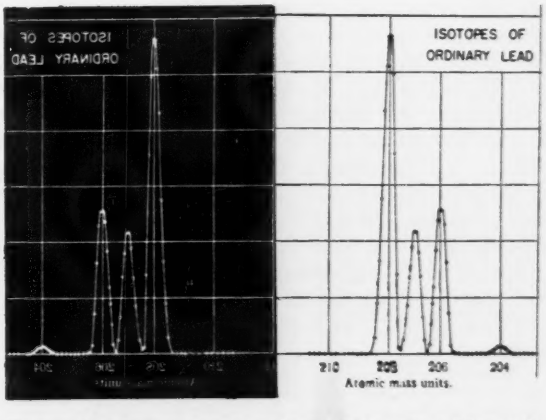

FIGURE 2.—DIRECT CONTACT COPY (REFLECTION METHOD) AND ITS POSITIVE ON PAPER

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Material which is already available in black and white, as in a book or typed page, can be very readily copied photographically. Two classes of such material may be distinguished: first, that in which the copy is not as large as a standard slide and, second, that in which the copy is larger than a slide. In the first case, two situations may be treated separately; first, if the material is printed on only one side of the page, and, second, if both sides are printed.

In the first case, where the material to be copied is not as large as a standard slide and is printed on only one side, the extremely simple method of *transmission* can be used. In this case, a paper negative is made by passing light through the printed page onto a piece of photographic paper. This is developed and then printed onto a film or photographic slide to make a positive transparency. Thus, in one specific case, a paper negative was made using Velox F-5 paper. The sensitized paper was placed emulsion side up and the material to be copied placed in contact with the emulsion. These were pressed together tightly with a heavily weighted piece of plate glass. *Intimate contact between the paper and the material to be copied is essential.* The upper blank surface of the page to be copied was then illuminated with a type A Photoflood bulb held in a desk lamp at a distance of two feet. (The light therefore passed through the glass plate, then through the blank side of the page, then through the printed side of the page, finally striking the sensitized emulsion

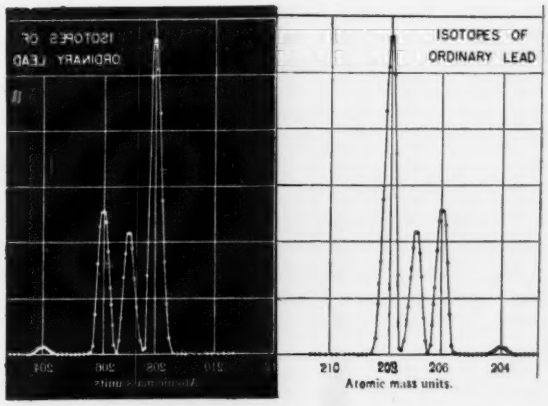

FIGURE 2.—DIRECT CONTACT COPY (REFLECTION METHOD) AND ITS POSITIVE ON PAPER

of the Velox paper.) After exposure of 45 seconds, the paper was developed,[7] fixed, dried, and printed on Eastman Process Film. (Unfortunately Process Film is not sold in slide size, but the $3^1/_4'' \times 4^1/_4''$ size may be purchased and cut to size, or the $8'' \times 10''$ sheets may be cut into six pieces and the trimmings used as test strips to determine proper exposures.) The positive transparency is made exactly as in printing a paper positive, *i. e.*, the emulsion side of the film is placed in intimate contact with the emulsion side of the negative and light is passed through first the negative (in this case a paper negative) onto the positive (in this case a film positive). A 15-second exposure to the light from a $7^1/_2$-watt bulb at a distance of two feet was adequate. The film was processed in the normal fashion to produce the finished film positive. This was then sandwiched between glass plates to produce the completed slide.

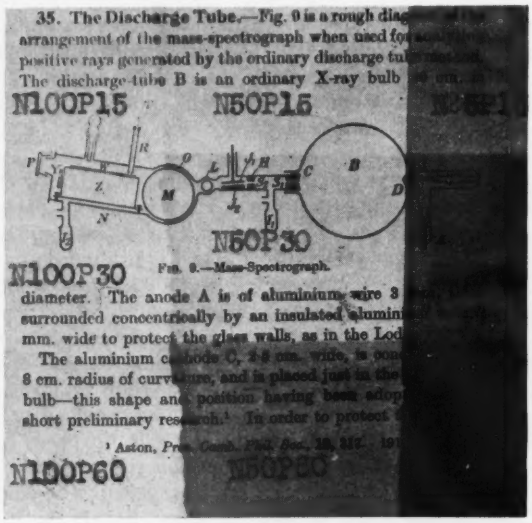

FIGURE 3.—PROCESS FILM TEST STRIP

(The legend indicates the length of exposure of negative and positive. Thus N100P15 means that the negative was exposed for 100 seconds and the positive printed for 15 seconds.)

If the material to be copied is printed on both sides the transmission method cannot be used. However, a *reflection* method can be used in this case (Figure 1). A piece of black paper is placed beneath the under side of the page to be copied. Velox paper is placed emulsion side down, directly in contact with the material to be copied, and pressed down firmly with a weighted glass. This is then illuminated with a Photoflood. Here the light passes through the glass plate, strikes the rear of the Velox paper; some passes through the paper to the emulsion, continues on to the printed page beneath, and is reflected back from the white portions of the printed page. This reinforces the effect produced on the sensitized emulsion on the first passage. This method seems to owe its success primarily to the induction period which characterizes photographic emulsions. When this exposed paper is developed, a mirror-image paper negative is obtained. (See Figure 2.) This may then be printed to produce a positive transparency or slide.

In a typical case a Velox F-5 paper negative made by an 11-second exposure to a Photoflood in a desk lamp at a distance of two feet was processed and printed on Eastman Process Film by a 15-second exposure to a $7^1/_2$-watt lamp held at a distance of three feet.

The reflection method can also be used if the material to be copied is printed on only one side and has one advantage over the transmission method. The length of exposure in making the negative by the reflection method is quite uniform, depending primarily upon the type of sensitized paper used. For Velox F-5, this is about ten seconds, but the exposure time is not very critical and may safely be varied by about 20 per cent. In the case of the transmission method, the length of exposure varies with the opacity of the page to be copied and may vary from ten to sixty seconds. A moderate amount of over- or under-exposure of the negative can be corrected in printing the positive but this requires some experimentation.

If the material to be copied is larger than a slide some method of reduction is necessary, but the projector itself may be used as a copying camera. A previously prepared slide is focused on the material to be copied and the projector lens is stopped down with a pierced cork. The light from the projector is turned off, the slide replaced by a piece of photographic paper or film held between cover glasses or an unexposed lantern slide, emulsion side toward the object to be copied. This is then illuminated with a Photoflood in a desk lamp held as level with the projector lens and copy as possible. If the copy is printed on very glossy paper or is badly wrinkled, it may be necessary to use two lamps at an angle of 45 degrees. A glossy or highly reflective surface requires a shorter exposure.

In a typical case, the projector lens was stopped down with a cork bored with a No. 7 cork borer and masked with a piece of black paper pierced with a No. 5 cork borer. This produced a sharp hole nine millimeters in diameter and, effectively, a lens opening nine millimeters in diameter. News Bromide paper was used for the negative and given an exposure of 150 seconds to a Photoflood held in a desk lamp at a distance of three feet. This was then processed and printed on Process Film by a 12-second exposure to a $7^1/_2$-watt lamp at a distance of three feet.

Bromide paper and Process Film have about the same emulsion speed but Process Film is about $2^1/_2$ times as fast as Eastman Contrast Slides. That is, a Contrast Slide requires about $2^1/_2$ times as long exposure. Exposure time is not at all critical and poor

[7] The developer used in all cases, both for paper and film, was Eastman D-72. This may be obtained in package form ready for solution or may be compounded from the published formula. Developing was continued for the time suggested by the Eastman Company for the particular film or paper used.

timing can often be corrected in printing. However, some experimentation will be necessary to familiarize oneself with the effect of various exposures. For this, Bromide paper may well be used as it is considerably cheaper than film. With a recommended procedure for testing, a wide latitude of exposures is permissible. In one case, Process Film was used, two-thirds of the copy was covered with black paper and illuminated for 50 seconds, then another third was uncovered and the whole again illuminated for 25 seconds and finally the remaining third was uncovered and the whole illuminated for another 25 seconds. This resulted in an exposure of three vertical strips on Process Film for 100, 50, and 25 seconds. This was then processed and printed on Process Film, but the printing was varied by using horizontal blocking strips and allowing 15, 30, and 60 seconds for printing exposures. (In testing, successive exposures should in all cases be at least doubled as smaller variations are not significant.) That exposure time is not at all critical, may be seen from the fact that in Figure 3 either the lower left portion or the upper middle portion would produce acceptable slides, yet in the one case the negative received an exposure of 100 seconds and the positive 60 seconds, whereas in the other case the negative was exposed for 50 seconds and the positive for 15 seconds.

Film or slides can, of course, be used for making the negative and the negative can itself be used fairly satisfactorily for projection to small groups if the negative is somewhat underexposed. Typically, an Eastman Contrast Slide, exposed for 20 seconds to a Photoflood at a distance of three feet, produced a light negative which could be used directly as a lantern slide. The advantage is that the time and cost of the second step of converting the negative to a positive are eliminated; the disadvantage is that the image is rather dark and not too clearly legible when projected for long distances.

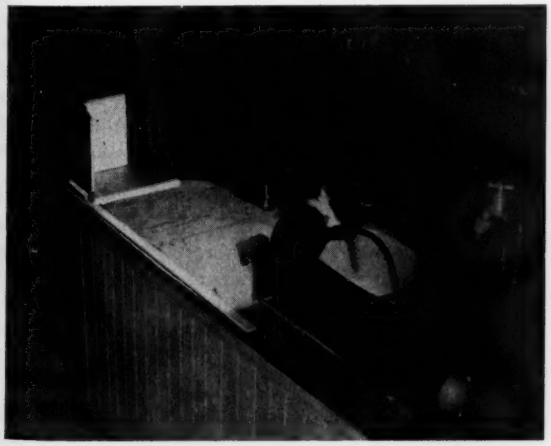

FIGURE 4.—SETUP SHOWING PROJECTOR USED AS A COPYING CAMERA

FIGURE 5.—CLOSEUP OF STOPPED DOWN LENS ON THE PROJECTOR WHEN USED AS A COPYING CAMERA

Direct positives can be made by reversal also—that is, by exposure, developing (as in D-72), bleaching in a chromate bath, clearing with bisulfite, re-exposing, redeveloping, and fixing. This will produce a fairly satisfactory positive image directly. If material is to be typed and then transferred to a slide, it is convenient to use the impression from white "carbon" paper on black paper, photograph that and develop and fix in the normal fashion to produce a black-on-white positive transparency directly.

Film slides can be prepared by using a projector as a camera (Figure 4), either by masking out all but a 2″ × 2″ portion of the slide area of a standard projector (Figure 5) or by using the regulation 2″ × 2″ projector itself as a camera. Surprisingly enough, a somewhat shorter exposure time is required in making the smaller slides (even when using the large projector and mask as a camera) than in making the larger slides.

The film strips obtainable from Bibliofilm Service, Washington, D. C., can be mounted separately and make satisfactory slides.

Dufay color pictures may also be taken, using a projector as a camera. The particular advantage of this method (over Kodachrome, for example) is that pictures may be taken in convenient slide size and processed immediately. Such color slides are not entirely satisfactory and much of the color obtained on projection depends upon the nature of the screen and the projector used.

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ACID-BASE REACTIONS[1]

Their Analogy to Oxidation-Reduction Reactions in Solution

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INTRODUCTION

TEACHERS and textbooks of elementary chemistry are swinging more and more toward the Brønsted theory of acids and bases to the exclusion of the older view [(*1*), (*2*), (*3*)]. This offers the possibility of combining the teaching of acidity and oxidation in a very attractive way.

For a long time chemical reactions have been classified into two large categories: oxidation-reduction (*o/r*), and the rest of the reactions. The latter class included double decomposition reactions, of which neutralizations, or, more properly, acid-base (*a/b*) reactions were one type. It is proposed to show in this paper that *a/b* reactions are not double decomposition reactions, but are closely analogous to *o/r* reactions.

OXIDATION-REDUCTION REACTIONS

By definition, a reducer is an electron donor. An oxidizer is an electron acceptor. An *o/r* reaction is one in which a reducer loses an electron to an oxidizer. A reducer cannot demonstrate its reducing power unless an oxidizer is present, and vice versa. The reaction is a *mutual* affair between oxidizer and reducer.

The driving force of the reaction is really the electron affinity of the oxidizer, because the reducer does not actually repel electrons. On the contrary, it requires the expenditure of considerable energy to remove an electron from a reducer. This work is done by the oxidizer by means of its strong electron affinity. It is thus clear that the terms donor and acceptor are in a certain sense misnomers. The reducer's "donation" is a forced one, and the oxidizer's "acceptance" is of a very active variety. It is rather like saying that a man "accepts" a stone which the ground "gives" him as he lifts it. More appropriate terms might be "electron loser" and "electron winner."[2]

ACID-BASE REACTIONS

By definition, an acid is a proton donor. A base is a proton acceptor. An *a/b* reaction is one in which an acid loses a proton to a base. An acid cannot demonstrate its acidity unless a base is present, and vice versa. The reaction is a *mutual* affair between acid and base.

The driving force of the reaction is really the proton affinity of the base, because the acid does not actually repel protons. On the contrary, it requires the expenditure of considerable energy to remove a proton from the acid. This work is done by the base by means of its strong proton affinity. Thus the terms "donor" and "acceptor" might profitably be replaced by "loser" and "winner."

DISCUSSION

A comparison of the last two sections will show that they are mere paraphrases of one another, the words "electron," "reducer," and "oxidizer" being the analogs of the words "proton," "acid," and "base." Furthermore, amphoterism exists among oxidizers and acids alike: HSO_4^- is both acid and base; Sn^{+2} is both oxidizer and reducer.

The analogy between *a/b* and *o/r* reactions remains valid even after closer consideration of the detailed physical mechanism of the processes in question. During *o/r* reactions, an electron is extracted from the valence shell of one atom and inserted into that of another. Can it be said that during an *a/b* reaction a proton is extracted from the valence shell of one atom and inserted into that of another?

Hydrogenous compounds are unique among molecules because the core of the hydrogen atom, alone among atomic cores, is a bare nucleus. In any other atom the core, consisting of the nucleus plus any completed shells of electrons below the valence shell, is immensely larger because of the presence of at least one such completed shell. Atomic cores have diameters of 1 to 2 A. Bare nuclei (including the proton or core of the hydrogen atom) have diameters of the order of 10^{-5} A., and so are almost incomparably smaller. The "thickness" of the valence shell of an atom is not, of course, very definite, but will be at least 0.1 A. Hence it is easily possible for the proton to bury itself in the valence shell of the atom to which it is attached, whereas it is impossible for the core of any other atom to do the same thing.

Semi-quantitative pictures of the arrangement of electrons and protons in hydrogenous molecules have been published (*4*) showing how the proton embeds itself in the valence shell of another atom. Hence it may be said truthfully that hydrogenous molecules possess valence shells which are composites of protons and electrons, and if a proton is lost by the molecule it has come from the valence shell.[3]

[1] Presented before the Division of Chemical Education at the one hundredth meeting of the A. C. S., Detroit, Michigan, September 9–13, 1940.

[2] "Electron snatcher" would be a more descriptive and striking term!

[3] It is probably superfluous to state that the proton which is transferred cannot possibly come from the nucleus of the atom concerned any more than electrons can be extracted from completed shells of the core by the energy available in a chemical reaction.

The analogy is thus complete, even in the intimate details of the transfer of proton and electron, respectively.

Why are *a/b* reactions usually classified among the double decomposition reactions, whereas *o/r* reactions are not? Chiefly because the protons are represented explicitly in the equation by a symbol, H, whereas the electrons are represented only indirectly by the charges assigned to the various elements present. Also because reactions are customarily written in the molecular rather than in the ionic form.

Some schemes for balancing *o/r* equations include as one step the formation of half-equations showing the action of oxidizer and reducer separately, thus:

$$Mg^{\circ} = Mg^{+2} + 2\epsilon, \quad {}^1/_2O_2{}^{\circ} + 2\epsilon = O^{-2}$$

Compare these with the half-equations

$$HCl = Cl^- + p, \quad OH_2 + p = OH_3^+$$

On one side of the first two equations the electrons are represented only implicitly in the charges assigned to the elements, but in the last two equations the protons are explicit on both sides as *p* and H, respectively.

When the half-equations are combined, all trace of the electrons will have been lost:

$$Mg + {}^1/_2O_2 = MgO$$

On the contrary, the protons will still be explicit:

$$HCl + OH_2 = Cl^- + OH_3^+$$

The usual type of double decomposition reaction is an ionic reaction in which one pair of ions is removed from the sphere of activity by precipitation, volatilization, or the formation of a very slightly ionized complex. The last is usually exemplified by the typical neutralization of a hydroxide by an acid:

$$NaOH + HCl = NaCl + OH_2 \text{ (un-ionized)}$$

Written in the true ionic form, however, it is clearly not a combination of H^+ and OH^- to form un-ionized OH_2, but rather a transfer of a proton from OH_3^+ to OH^-:

$$OH_3^+ + OH^- = OH_2 + OH_2$$

Any other type of double decomposition is more truly a combination of ions to form long-lived complexes:

$$Ba^{+2} + 2Cl^- + Mg^{+2} + SO_4^{-2} = BaSO_4 + Mg^{+2} + 2Cl^- \quad (A)$$

THE CLASSIFICATION OF CHEMICAL REACTIONS

It is illuminating to review the usual classification of chemical reactions in the light of the preceding discussion. Consider the types called: (1) combination, (2) decomposition, (3) displacement, (4) double decomposition, (5) neutralization, (6) oxidation. There are two objections to this scheme or to one of its variants. First, such a classification is never unique:

(1) Combination may or may not involve oxidation:

$$2Hg + O_2 = 2HgO \qquad (o/r) \qquad (B)$$
$$H_2O + SO_3 = H_2SO_4 \qquad (\text{not } o/r)$$

(2) The same is true of decomposition, which, after all, is only a combination read from right to left:

$$2HgO = 2Hg + O_2 \qquad (o/r)$$
$$H_2SO_4 = H_2O + SO_3 \qquad (\text{not } o/r)$$

This pair of types can never be considered as *a/b* reactions, however, because the typical *a/b* reaction is

$$\text{acid} + \text{base} = \text{base} + \text{acid}$$

which requires two species on each side of the equation with few exceptions.

(3) Displacement can always be classified as oxidation or neutralization:

$$Zn^{\circ} + Cu^{+2} = Zn^{+2} + Cu^{\circ} \qquad (o/r)$$
$$SiO_2 + Na_2CO_3 = Na_2SiO_3 + CO_2 \qquad (\text{not } o/r)$$

When written ionically, the last reaction conforms to an extended definition of acidity, and is often referred to as "the displacement of a volatile acid by a non-volatile one":

$$SiO_2 \text{ (acid)} + CO_3^{-2} \text{ (base)} = SiO_3^{-2} \text{ (base)} + CO_2 \text{ (acid)}$$

(4) Double decomposition reactions, as has been shown, should not include neutralizations as a subclass. Apart from *a/b* reactions, the processes commonly placed in this group are more properly included under the head of combination. For example, equation (*A*) above, written ionically:

$$Ba^{+2} + SO_4^{-2} = BaSO_4$$

The second objection to the usual classification is that it fails to emphasize the essential reversibility of all reactions. It is not wise to accustom the student to read an equation always and only from left to right, Every typical process has its inverse: for oxidation there is reduction; for acidifying, "alkalizing"; for combination, decomposition.

CONCLUSION

A rational classification of reactions would thus be: (1) *a/b*, (2) *o/r*, (3) *c/d* (combination-decomposition), in which the *mutual* relationship of the inverse processes is manifested and in which the number of classes is reduced to three. Many reactions would still be placed in more than one category (for example, reaction (*B*) above), but even this ambiguity could be avoided by using the *c/d* class only if the process fails to fall into the class of *o/r*.

Reactions represented by complex equations may naturally fall into more than one class. For example, nearly all *o/r* reactions involving oxygenous ions are *a/b* reactions as well, since protons are definitely transferred and the acidity of the solution is altered:

$$2KMnO_4 + 10FeSO_4 + 8H_2SO_4 = K_2SO_4 + 2MnSO_4 + 5Fe_2(SO_4)_3 + 8H_2O$$

or $$MnO_4^- + 5Fe^{+2} + 8OH_3^+ = Mn^{+2} + 5Fe^{+3} + 12H_2O$$

The ionic equation is the simplest possible for the overall reaction, although it is recognized that the actual reaction undoubtedly proceeds in steps much simpler than that represented by this equation. Here definitely there is *a/b* as well as *o/r*, into which latter class the reaction is commonly placed.

With the growing emphasis, even in elementary chem-

istry, upon ionic equations and modern theories of acidity, it would seem feasible to reduce the number of descriptive terms applied to types of reaction to the three mentioned above, and to stress strongly the analogy between *a/b* and *o/r* reactions. To the beginner, chemistry is already sufficiently complex and bewildering.

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NOTES ON THE DEMONSTRATION OF "WETTER" WATER

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FIGURE 1

IN THE August, 1939, issue of this JOURNAL, Drs. Hauser and Reynolds complimented the author's sinking of a duck in "wetter" water as an ingenious method of demonstrating the action of a powerful wetting agent. Pointing out the disadvantages in the use of ducks, they presented a simpler demonstration of reduction of surface tension, using toy battleships so constructed that they would sink when a wetting agent was added to the water. Witnesses of this demonstration have reported it to be most effective.

However, with both the ducks and the battleships, considerable preparation is needed in advance. The following suggestions are therefore made for those who wish to demonstrate the remarkable surface-tension reducing powers of the modern synthetic wetting agents, but who may have only a few minutes in which to prepare the experiments for the lecture table.

As everyone knows, powdered sulfur will float indefinitely on the surface of water without becoming wet. The addition of a few drops of a concentrated solution of Aerosol OT (the di-octyl ester of sodium sulfosuccinate) to the surface of the water on which the sulfur floats causes it to sink immediately—a very effective demonstration. All that is necessary is a beaker of water, a few grams of powdered sulfur, the solution of Aerosol OT, and a stirring rod or eyedropper.

An even more startling demonstration is illustrated in Figure 1. The beaker on the right contains only water, that on the left water plus 0.1 per cent Aerosol OT. Powdered sulfur is poured from both hands into the beakers and as shown, it does not penetrate the surface of the pure water but pours like sand into the beaker of "wetter" water containing the Aerosol OT. Everything necessary for this demonstration can be assembled in a few minutes.

Similarly, in Figure 2, ordinary string is let slowly down into the two beakers. It does not get wet in the pure water and floats on top, but in the beaker containing Aerosol OT it wets instantly and sinks beneath the surface. Two wads of raw wool or cotton may be used instead of the string, with equally startling results.

If the lecturer prefers to show a ship sailing on the water instead of the sinking of enemy battleships, a little more preparation is needed than for the above-mentioned experiments. A gram of Aerosol OT pressed onto the stern of a toy ship (preferably a balsa-wood model) will propel it back and forth across a tank of water for hours. Taken home after the lecture, this device launched in the bathtub full of water is guaranteed to keep the children amused for many a rainy day. The warmer the water, the greater the speed of the boat will be.

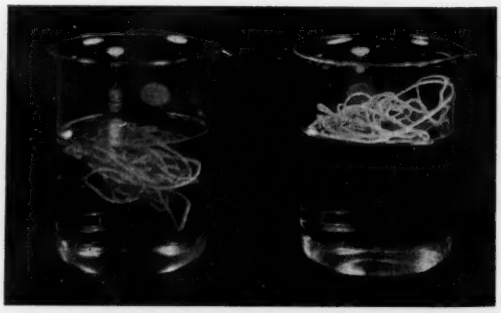

FIGURE 2

LECTURE DEMONSTRATIONS *in* GENERAL CHEMISTRY[1]

SAUL B. ARENSON

University of Cincinnati, Cincinnati, Ohio

6. DEMONSTRATING THE REALITY OF MOTION AND OF COLLISION OF GAS MOLECULES[2]

PREPARE two small (one-cc.) thin-walled glass bulbs ending in a drawn-out tip (similar to a Dumas bulb except for size). Fill these bulbs partially with liquid bromine by the usual procedure of alternately warming and cooling the bulb while the tip is held underneath the surface of liquid bromine. (*Caution:* Work in a well-drawing hood; do not get bromine on the hands!) Seal off the tip with a flame.

Remove the glass stopper from one of two tall (4000-cc.) glass-stoppered measuring cylinders, and substitute a one-hole rubber stopper equipped with a glass stopcock. Carefully slide a bromine bulb down to the bottom of each cylinder. Close one cylinder with its glass stopper and the other with the prepared rubber stopper. By means of a mechanical vacuum pump evacuate to about 15 mm. the cylinder equipped with the stopcock.

By a quick double inversion of the cylinders, the bromine bulbs are broken as they strike the bottoms of the cylinders. In the cylinder *filled with air*, the bromine vapor rises only to about one-eighth of the height of the cylinder; in the *evacuated* cylinder, the bromine vapor almost instantaneously fills (or nearly fills) the cylinder. The deep color of the bromine vapors can be seen by students in the rear of the lecture room if the cylinders are placed in front of a white background.

Thus the student can observe the upward motion of the colored bromine vapor (*i. e.*, the mass movement of bromine molecules) in both cylinders. In the air-filled cylinder, the mass movement is slow because of the large number of collisions with air molecules. In the evacuated cylinder, where the concentration of air molecules is very much smaller, the mass movement of bromine molecules is very rapid because of this lack of collision. Thus, the demonstration shows (*a*) that molecules of a gas actually move and (*b*) that molecules actually collide.

7. TO SHOW HOW THE DEGREE OF ION FORMATION IN AN ELECTROLYTE MAY BE MEASURED[3]

A tall glass cylinder of small diameter is fitted with two long copper electrodes extending the whole length of the cylinder. These electrodes are connected to the lighting circuit in series with a large ammeter and a lamp. A little glacial acetic acid is placed in the bottom of the cylinder and a stirring device is adjusted to keep it agitated. When the circuit is closed, no current flows, but as distilled water is added drop by drop, the conductivity gradually increases until the maximum flow of current is obtained. The student can follow the ion formation by watching the ammeter and the lamp.

8. IONIC MIGRATION[4]

The following demonstration is based on the experiment described in Stieglitz's "The Elements of Qualitative Chemical Analysis."

The apparatus, Figure 8, consists of a U-tube of about 16-mm. bore. The total length of the tube from one open end to the other is about 51 inches. It is supported in a suitable manner and an electrode provided for each end of the tube. The electrodes are made by fusing a platinum wire into the end of a glass tube of about 5-mm. bore and making contact with a copper wire by means of a few drops of mercury.

The tube is prepared as follows: To 250 ml. of cold water, add 12.5 grams of powdered agar agar and 17 grams solid KCl. (The amount of agar agar used may vary from two to five per cent. The amount given is about right for powdered agar agar, the flake seems to require less.) Stir until well mixed and heat on a water bath for about an hour. Stir occasionally.

Clamp the U-tube in a vertical position. Remove the mixture from the water bath and pour enough into the U-tube to fill the bend in the tube. Place the mixture back on the water bath until that in the tube has firmly set, then remove it from the bath and add four ml. stock phenolphthalein solution (1 g./50 ml. alcohol + 50 ml. water). Divide the mixture into two equal parts and to one add five to ten drops of 10 per cent KOH solution and stir until well mixed. This portion should have a nice red color. Holding the beaker containing the red portion in one hand and that containing the colorless portion in the other, pour one into one arm of the tube and at the same time pour the other into the other arm. The levels should be kept as nearly equal as possible to avoid building up any pres-

[1] Continued from the September, 1940, issue.

[2] Contributed by W. A. Felsing, Professor of Chemistry, University of Texas.

[3] Contributed by E. L. Quinn, Professor of Chemistry, University of Utah.

[4] This and the following demonstration were contributed by Colonel C. L. Fenton, Professor of Chemistry, U. S. Military Academy.

sure on the agar agar which has already set. In this way fill each arm to within six inches of the top of the tube. A strip of black paper about $^3/_{16}$" wide is glued around each arm of the tube at the top of the agar agar column.

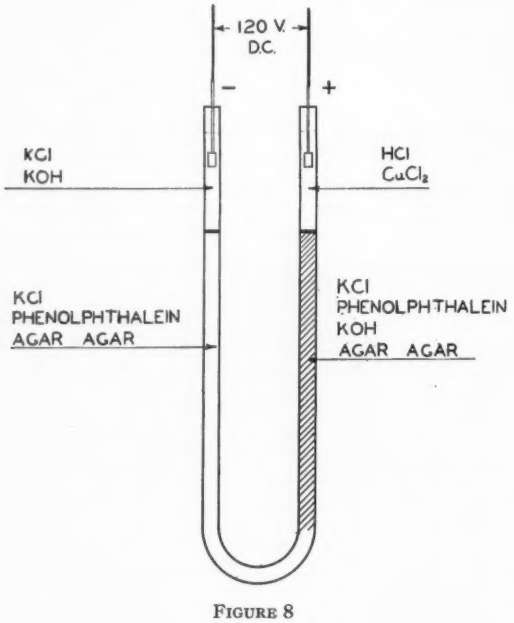

FIGURE 8

The space above the agar agar is now filled with the following solutions to within an inch of the top.

Red arm	*Colorless arm*
1 ml. conc. HCl	5 ml. 10% KOH
12 ml. $CuCl_2$ soln. saturated	5 ml. water
40 ml. water	40 ml. KCl soln. saturated

The electrodes are now lowered in the solution and an E.M.F. of 110 volts D.C. is applied. The resistance of the tube as described is about 550 ohms. At the end of an hour, the red arm below the black strip will have become colorless due to the action of the H^+ on the phenolphthalein for a distance of about $3^1/_2$". Immediately under the black strip a blue zone about one inch long due to the Cu^{++} will be seen, and in the other arm a red color will have developed due to the action of the OH^- for a distance of about two inches. The relative velocities of migration of these ions are thus shown.

In an hour's time the tube will become somewhat warm, and if the current is allowed to flow much longer than this the agar agar may soften and rupture.

9. CONDUCTANCE AND IONIZATION

The following demonstration has been developed to illustrate ionic equilibrium reactions and the "apparent degree of ionization" and conductance of solutions.

The experiment consists of measuring the conductance, as indicated by an ammeter, of a cell (Figure 9) which contains equivalent amounts of two salt solutions separated by a more or less insulating layer of water. An analysis of the ionic equilibrium diagram for this pair of solutions will indicate the change that will take place in the conductance of the cell when the two solutions are mixed and allowed to come to equilibrium with each other. The solutions are then actually mixed and the change of conductance, if any, noted on the ammeter.

Since the values of conductance noted are only relative, the various factors which would affect the conductance of a cell of this kind are limited, for all practical purposes, to the total number of ions between the electrodes at any given time.

The apparatus required consists of a conductivity cell of a type similar to that shown in Figure 10, a D.C. ammeter (0–1 ampere; a lecture table galvanometer with a one-ampere shunt is excellent), a source of D.C. voltage from 8 volts to 120 volts, and a separatory funnel of 250 ml. capacity, stirring rod, solutions, etc. A separate cell will be required for each pair of solutions used; usually a number of cells are connected in parallel and the ammeter is placed in the supply line so that any cell may be placed in the circuit at will.

The cell shown in Figure 10 consists of a glass battery jar of rectangular shape about 2" × 5" × $6^1/_2$" deep mounted on a wooden base about $1^1/_4$" × 6" × $6^1/_4$". A recess is mortised into the base $^5/_8$" deep in which the jar fits. Binding posts and a switch are mounted on the base. The permanent wiring of the base terminates at two wood screws, with washers under the heads, one at each side of the base block at the ends of the jar.

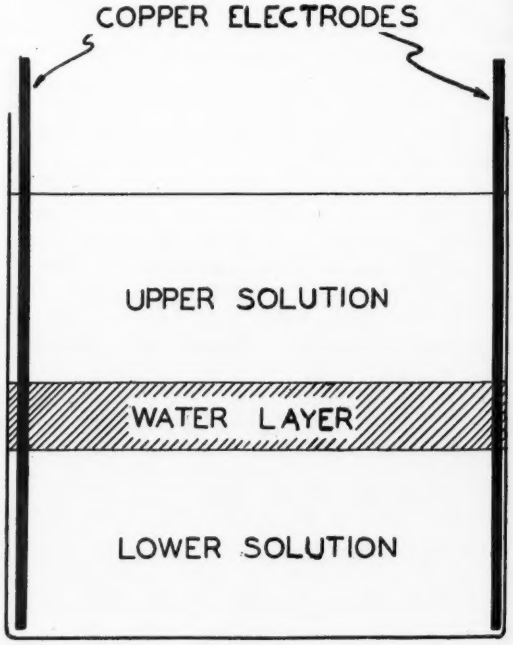

FIGURE 9

Connection is made to the electrodes by a flexible lead which is soldered to the electrode and has a lug which slips under the screw head at the other end. A twist of a screw-driver and the jar with the electrodes can be removed from the base for cleaning. The electrodes are made from 20-gage sheet copper cut to the width of the glass jar and long enough so that the upper end can be bent over, forming a clip to hold the electrode in place. The electrode thus covers the entire end of the cell.

We use the seven pairs of solutions shown in the following table. There are undoubtedly others which could be used, but it is believed that these seven bring out most of the important points.

Pair No.	*Upper solution*	*Lower solution*	*E.M.F. used*	*Result of mixing on conductivity*
1	*N*/10 KCl	*N*/10 $NaNO_3$	12 v.	None
2	*N*/10 NH_4Cl	*N*/10 NaOH	16 v.	Decrease
3	*N*/10 HCl	*N*/10 NaAc	8 v.	Decrease
4	*N*/10 HAc	*N*/10 NH_4OH	48 v.	Increase
5	*N*/10 NaOH	*N*/10 HCl	8 v.	Decrease
6	*N*/40 Ag_2SO_4*	*N*/40 $BaCl_2$*	72 v.	Decrease to zero
7	Glacial HAc	Water	80 v.	Increase

* Use distilled water and carbon electrodes.

A quantity of colored weighted water will be required and is prepared as follows. One gram of red aniline, or other water-soluble dye, is dissolved in about 500 ml. hot water and the resulting solution diluted to two liters. Five hundred grams of ordinary cane sugar are added.

Three hundred ml. of each solution (except pair No. 7) are poured into suitable containers and 150 grams of sugar are added to each of the solutions listed as "lower" in the table. In the case of pair No. 7, 100 ml. of glacial acetic acid are placed in one container and 800 ml. of the colored water prepared above are placed in the other.

The cells are filled by first pouring the "upper" solution into the jar, inserting the separatory funnel, and, with the stopcock open, applying suction to the mouth of the funnel until the stem is *completely* filled with solution. If any excess solution is drawn up into the bulb of the funnel it must, of course, be allowed to return to the jar, but the stopcock must be closed before any air enters the stem. One hundred ml. of the colored water are now poured into the funnel and the stopcock opened a little. The colored water will form a layer under the "upper" solution and raise it as the jar fills. The stopcock must be closed before any air enters the stem. The "lower" solution of the pair is now poured into the funnel and the stopcock opened as before until the bulb is empty. Again, the stopcock must be closed before any air enters the stem. If it is found necessary to add liquid to the funnel bulb the stopcock should be closed while this is done, as otherwise air bubbles will get into the stem of the funnel. The funnel is now carefully removed from the jar and the cell presents the appearance shown in Figure 9.

In use, an analysis of the corresponding ionic equilibrium diagram is first made, *e. g.*, in the case of the second pair (NH_4Cl and NaOH) the following diagram is used:

$$\begin{array}{lcccl} & 1.3\% & & 84\% & \\ NH_4Cl \rightleftharpoons & NH_4^+ & + & Cl^- & 70\% \\ & + & & + & \\ NaOH \rightleftharpoons & OH^- & + & Na^+ & 91\% \\ & \downarrow\uparrow & & \uparrow\downarrow & \\ & NH_4OH & & NaCl & \\ & 98.7\% & & 16\% & \end{array}$$

From this diagram it is concluded that there are fewer ions between the electrodes of the cell after mixing than before and therefore the conductance will be less. The appropriate voltage is applied, according to the table, the switch closed and the ammeter reading noted. The two solutions are then thoroughly mixed and any change in the ammeter reading noted.

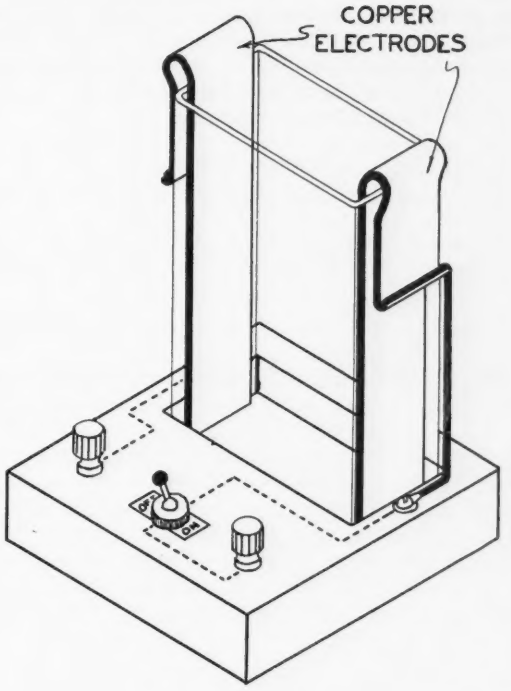

FIGURE 10

Cell No. 7 consists of a thin layer of glacial acetic acid over 800 ml. of colored water. Upon mixing the conductance of the cell is, of course, increased.

Cell No. 6 requires a little special consideration. As can be seen, the end-products are practically insoluble and therefore the conductance drops close to zero. In order for this to be shown successfully (1) carbon electrodes must be used instead of copper; otherwise the silver will deposit and the copper go into solution while the cell is standing; (2) exactly equivalent amounts of the two solutions must be used; and (3) allowance must be made for the fact that in removing the funnel from the cell a considerable amount of the lower solution is also removed.

In most of the solution pairs it will probably not make much difference which solution is made the lower one, but it is quite necessary in the case of pair No. 6 that the $BaCl_2$ solution be made the lower one, because the sugar will quickly invert and reduce the silver if it is added to the Ag_2SO_4 solution.

It has been found impractical to illustrate some of the "borderline" cases not only because of the small change in conductance involved but because of the effect of the sugar on the conductance of the solutions. For example, the conductance of a $N/10$ NaAc solution, measured with a conductance bridge, was found to be more than three times that of a similar solution consisting of 300 ml. of $N/10$ NaAc to which 150 grams of sugar had been added. Consequently, unless the change in ionic conductance is considerable, it is apt to be masked by the effect of the sugar.

10. IODINE ON TURPENTINE[5]

Take about 10 grams of solid iodine, crushed just a little in a glass mortar, and with care pour on around five to ten ml. of turpentine.

This demonstration came to me as follows: I visited a farm in the Rio Grande valley. An old-time "horse doctor" was there just ahead of me. A horse had a very large abscess. The "doctor" worked crystals of iodine into the sore and poured on turpentine. The farmer was impressed. So was the horse.

11. DIFFERENT RANGES OF EXPLOSIBILITY OF AIR-GAS MIXTURES

I find a toy calcium carbide cannon useful in showing (very roughly) the different ranges of explosibility of air-gas mixtures. In our large lecture room we have natural gas (methane, mostly). It is difficult to run in gas from a burner (cork in muzzle of cannon) and get an explosive mixture (5 per cent to 13 per cent in air). Many attempts result in failure; indeed, failure is the usual result. Water and carbide result almost always in an explosion the first time the attempt is made with the acetylene-air mixture, since its range is three per cent to 73 per cent.

(To be continued)

[5] This and the following demonstration were contributed by John D. Clark, Professor of Chemistry, University of New Mexico.

AN IMPROVED FORM OF THE COTTRELL BOILING POINT APPARATUS

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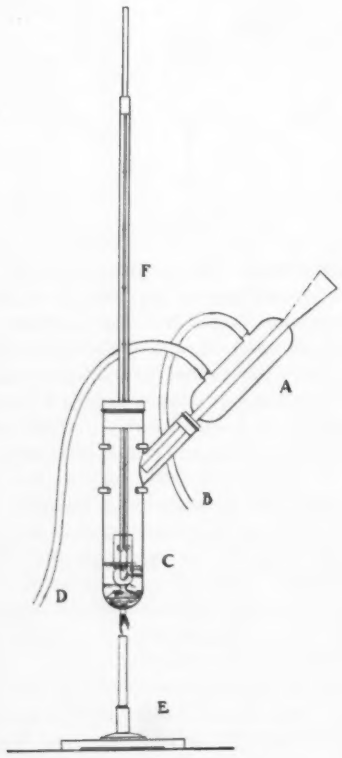

NEARLY every one who has used the original Cottrell boiling point apparatus for the determination of molecular weights has experienced difficulty in keeping a constant flow of liquid over the bulb of the Beckmann thermometer. The apparatus in the illustration eliminates this difficulty.

The condenser, *A*, is 30 cm. in its greatest length. It is sufficiently long to insure a minimum loss of solvent.

The outer tube, *C*, with the side neck for the condenser, is 24 cm. long and 5 cm. in diameter.

The overall length of the inner tube, opposite *C*, is 12 cm. It is not attached to *C*, but rests on the bottom of *C*. The hemispherical bottom is 4 cm. in diameter and 2 cm. high. A 6-mm. opening is provided at the union of it with the upright part of the tube. Four tips are pressed into the tube, one cm. from its top. These keep the Beckmann thermometer in the center. Four holes, 6 mm. in diameter, are made, 5 cm. from the top of the tube. These allow an overflow of the boiling solution.

No difficulty is experienced in keeping the temperature constant if the tube, *C*, is surrounded with an air bath (not shown in sketch) of galvanized sheet iron, and heated with a Bunsen burner. The bath is 20 cm. high and 10 cm. in diameter. The bottom of the bath is closed with an asbestos disc. An opening, 2 cm. in diameter, is made in the asbestos disc.

PLASTIC *and* ALLOTROPIC FORMS *of* SULFUR

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SULFUR appears in many allotropic forms, which are characterized by differences in solubility, specific gravity, crystalline form, etc. The varieties now called alpha-sulfur and beta-sulfur were discovered by Mitscherlich (*1*) in 1823. The former is the ordinary variety furnishing octahedral crystals belonging to the rhombic system. At 95.4°C. the rhombic form is in equilibrium with a monoclinic modification, beta-sulfur. With the absorption of 105 calories of heat for each 32 grams, rhombic sulfur is converted into the monoclinic (*2*).

Gernez (*3*) recognized another form of sulfur which he called gamma-sulfur. He obtained gamma-sulfur, mixed with some alpha- and beta-sulfur, when sulfur that had been heated to 150°C. was cooled to 90°C. and crystallization was initiated by rubbing the walls of the glass container with a glass rod. Gamma-sulfur crystallizes in the form of pale yellow-white, needle-like crystals with a mother-of-pearl luster. The crystals are monoclinic but they have different axial ratios from those of beta-sulfur.

A fourth modification of sulfur, also monoclinic, is called delta-sulfur. It is obtained in thin tabular crystals, mixed with some gamma-sulfur, when a solution of sulfur in alcoholic ammonium sulfide is cooled to 5°C. This form is so unstable that measurements of the crystal faces, etc., have not been determined.

Linck and Korinth (*4*) have found three other forms of sulfur—theta-, zeta- and nu-sulfur. Theta-sulfur is formed by the evaporation of a carbon bisulfide solution of sulfur thickened with Canada Balsam or rubber. It forms pale yellow tetragonal crystals. Zeta-sulfur forms colorless, rhombic plates which have a weak double refraction. The other variety, nu-sulfur, has colorless, doubly refracting, hexagonal plates.

These varying forms of sulfur have different stabilities, and at ordinary temperatures and pressures they change from one form to the other. Korinth (*5*) believes that the following transformations take place, with increasing stability from theta- through alpha-sulfur:

$$\text{Theta} \rightarrow \text{Delta} \rightarrow \text{Nu} \rightarrow \text{Zeta} \rightarrow \text{Gamma} \rightarrow \text{Beta} \rightleftharpoons \text{Alpha}$$

Different methods of determining the molecular weight of rhombic sulfur show that the molecule of the element in the solid state may be represented by S_8. Warren and Burwell (*6*) have shown by X-ray analysis that the crystal cell of rhombic sulfur contains sixteen molecules of S_8. The sulfur atoms in the S_8 molecule are linked together in a ring structure with an S–S distance of 2.12 Angström units. The ring is in the shape of a puckered octagon.

Sulfur melts at approximately 115°C., giving a pale yellow mobile liquid. Between 160°C. and 170°C. it becomes deep brown in color with a sudden and large increase of viscosity. The maximum viscosity is reached in the neighborhood of 200°C. Smith and Holmes (*7*) state that the peculiar behavior of molten sulfur may be accounted for on the assumption that liquid sulfur can exist in two states—one a pale yellow liquid called lambda-sulfur which predominates from the melting point to 160°C., and the other a brown viscous liquid, called mu-sulfur, which prevails above 160°C. Warren and Burwell (*6*) suggest that the formation of this highly viscous sulfur depends upon the S_8 rings breaking open and forming irregular chains which tangle with one another, thereby giving rise to the marked increase in viscosity.

The work of Kellas (*8*) on the measurement of the viscosity of molten sulfur indicates that the surface of molten sulfur is composed of inactive S_8 molecules and active S_4 molecules. He also found that between 117°C. and 155°C. the sulfur molecules existed as S_6 and between 160°C. and 444°C. the sulfur was in the form of S_{18} molecules. From this work it would seem that the sulfur undergoes an endothermal polymerization at about 160°C.:

$$3S_8 \rightleftharpoons (S_8)_3$$

The formation of this polymer of high molecular weight might account for the increase in viscosity.

Amorphous sulfur (mu) is insoluble in carbon bisulfide. It was first isolated and described by Deville (*9*). Work on the freezing point of sulfur has shown that amorphous sulfur may exist dissolved like a foreign body in soluble sulfur, indicating that amorphous sulfur is a distinct variety and is not solid monoclinic or melted soluble sulfur. Amorphous sulfur is formed as soon as sulfur melts and increases in amount as the temperature rises. The progressive increase of this amorphous sulfur, formed with rising temperature, indicates that the amorphous sulfur is generated by an endothermal reaction from the original soluble sulfur (*7*). Therefore, at ordinary temperatures amorphous sulfur is less stable than crystalline sulfur. The actual proportion that is present is determined by the reversible reaction (*10*):

$$\text{lambda-sulfur} \rightleftharpoons \text{mu-sulfur}$$

Above 160°C. only mu-sulfur is stable. Rapid heating

and the presence of certain foreign substances postpone the transition from lambda-sulfur to mu-sulfur. Conversely, the rapid cooling from temperatures above 160°C. postpones the transition from mu-sulfur to lambda-sulfur, and when conditions are favorable a large proportion of mu-sulfur may be found in the chilled product. The product obtained on rapid cooling is then a more or less plastic mass, which in time partly reverts to soluble sulfur and partly to a hardened, difficultly soluble form. The latter, like all amorphous substances, is a supercooled state of a liquid, namely mu-sulfur (*7*).

Berthelot (*11*) has assumed that sulfur present in different sulfur compounds is in different physical forms. That is, sulfur present as an electronegative element is soluble; when present as an electropositive element it is insoluble. He considers this to be shown by the experimental evidence that the electrolysis of an aqueous solution of hydrogen sulfide will give only soluble sulfur, which appears at the positive pole, while the electrolysis of sulfurous acid will give almost insoluble sulfur at the negative pole.

Lange and Cousins (*12*) have shown that as the temperature rises the complex S_8 molecules, in the molten state, dissociate into simpler molecules. They assumed, from the work of Aten (*13*) and Beckmann (*14*), that the dissociation followed the reversible reactions:

$$S_8 \rightleftharpoons 2S_4 \rightleftharpoons S_2 + S_6$$

The molecule S_4 was isolated by Aten (*13*) who called it pi-sulfur. At low temperatures S_2 is not stable and probably immediately polymerizes to S_4 and S_6 molecules. It has been suggested by some investigators that the S_6 molecules represent mu-sulfur, the variety insoluble in carbon bisulfide (*15*). The form of sulfur isolated by Engel (*16*) has been given the formula S_6 by other investigators; however, it is soluble in carbon bisulfide. At temperatures above 1800°C. the vaporized S_2 molecules dissociate into single atoms.

Above 160°C. sulfur is stable in an amorphous form. Sudden cooling yields a rubbery, elastic material which is unstable at ordinary temperatures. This plastic mass normally retains its elasticity for only a few hours after cooling below the transition temperature, for it gradually changes into the crystalline variety of the element. Crystallization begins in the center of the mass; that is, at the part where the cooling has been slowest (*17*). Kastle and Kelly (*18*) have shown that the rate of change of plastic sulfur into crystalline sulfur varies according to the temperature at which the sulfur is poured. It diminishes with the degree of supercooling and also with the temperature at which it is preserved. If the plastic sulfur is kept at a sufficiently low temperature it will not crystallize. Mondain-Monval (*19*) found that the temperature below which plastic sulfur would not crystallize was −29°C.

The work of Smith and Holmes (*7*) points out that the proportion of the different polymers in freshly prepared plastic sulfur cannot be accurately determined. They pointed out that the soluble crystalline sulfur, undoubtedly present, appears to be covered with the other forms of the element that are present, and that this entire particle tends to dissolve in carbon bisulfide. Alone, the crystalline variety cannot be obtained in a plastic condition. If the plastic mass is allowed to harden before analysis, a change in its composition is certain to take place. At normal temperatures plastic sulfur is in a metastable condition; therefore, on hardening, an undeterminable portion will pass into the soluble crystalline form. After the plastic mass has become hard and opaque the proportion of insoluble sulfur is easily determined by extraction. Once this stage has been reached the further transformation of insoluble sulfur into soluble sulfur proceeds very slowly. There is little reduction in the proportion of the former even when the sample is kept for months (*20*).

Plastic sulfur may also be obtained by the decomposition of certain sulfur compounds, such as the thiosulfates; by the interaction of hydrogen sulfide and sulfur dioxide; or by the decomposition of xanthates. Iredale (*21*) prepared plastic sulfur by treating powdered sodium thiosulfate with concentrated nitric acid. A yellow, transparent, elastic mass was obtained, which, after distention to four times its length, regained its original form. After twenty-four hours it passed completely into the crystalline form. Since the sudden separation of sulfur from a very concentrated solution is favorable to gel formation, Iredale regarded his elastic sulfur as the gel form of colloidal sulfur.

Von Weimarn (*22*) found that when sulfur heated above 400°C. was poured in thin streams into liquid air, the sulfur was obtained in the form of thin threads with a diameter of 0.5–1.0 mm. When these threads were warmed they became very elastic. The maximum extension of a thread about one mm. in diameter was approximately 5.5 times the original length, and if the extension was less than the maximum, the thread was able to return to its original length. The elasticity was lost in about thirty minutes after the thread was removed from the liquid air.

Apparently one condition necessary for the formation of plastic sulfur is that the S_8 rings be broken. Whether these broken rings are by themselves plastic or whether they undergo further polymerization has not been definitely settled. From the nature of the preparation of plastic sulfur it would seem that the plastic property is a function of the amorphous sulfur content. Hammick and Zvegintzov (*23*) suggested that amorphous sulfur is itself a gel, and confirmed their view by observing the Tyndall effect in pure molten sulfur. Some writers describe plastic sulfur as a distinct soluble variety of amorphous sulfur (*24, 25*). Erdmann (*26*) believed the formation of amorphous sulfur could be accounted for by the polymerization of thiozone S_3. From the X-ray analysis of Meyer and Go (*27*) it has been shown that plastic sulfur has a fiber structure. The sulfur atoms are arranged in long chains linked by covalencies arranged parallel to the direction of the fiber. On stretching, the fiber can be made to crystallize, though normally it is amorphous;

that is, the sulfur chains are tangled with each other.

Sulfur has been preserved in the plastic condition by the use of other chemicals. Dietzenbacher (*28*) found that iodine would confer unusually persistent plasticity on supercooled sulfur. Plastic sulfur of a relatively stable character was prepared by Hamor and Duecker (*29*) by heating a mixture of elementary sulfur and phosphorus sulfide to a temperature above 200°C. and rapidly cooling the resulting fluid to a temperature below the melting point of sulfur. Arsenic and thallium, or their oxides or sulfides, also act as stabilizers (*30*). The products prepared by treating phenol or its homologs with sulfur chloride also act as stabilizers for plastic sulfur (*31*).

Whatever the nature of plastic sulfur, it holds promise of great usefulness in the future. Trillat and Forestier (*32*) have shown that plastic sulfur, prepared by heating sulfur to a temperature above 250°C. and then pouring into cold water, stretches upon rapid drawing to a permanent lengthening of 800–1000 per cent. The sulfur was amorphous before drawing but the stretched fibers showed temporarily a characteristic orientation of the crystals in the direction of the axis of the fiber (*33*). Determination of the stress-strain curves of raw rubber and of plastic sulfur, in which data were recorded practically independent of plastic flow, showed that there is a marked similarity between the curves of these two substances (*34*). With a means of stabilizing this elasticity, plastic sulfur should in many instances be a satisfactory substitute for rubber.

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CONVENIENT METHOD FOR CONDUCTING THE KJELDAHL DIGESTION

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THE following procedure is suggested as a convenient one for conducting the digestion of samples in the Kjeldahl method for nitrogen when the usual digestion rack is not available, or for some reason cannot conveniently be used. The method has been tried out by students in the regular course in quantitative analysis, working in a crowded laboratory, and functions perfectly.

Prepare the sample for digestion in the usual manner. Select an ordinary Gooch filtering crucible of such size as to fit nicely in the mouth of the flask. Line the mouth of the flask with a gasket made of lead or tin foil, to provide a tight fit of the crucible in the mouth of the flask. With the crucible snugly in place, fill it about two-thirds full with medium or coarse fiber asbestos, loosely placed. Moisten the asbestos with concentrated sulfuric acid and proceed with the digestion. The choking acid fumes, copiously produced, are perfectly absorbed in the crucible, no hood or special equipment being necessary.

To shorten the time required for digestion of the sample, the use of some form of selenium catalyst is recommended. Of these, cupric selenite appears to be the most effective. For details concerning the use of this substance as a catalyst in the Kjeldahl method for nitrogen, see the *Journal of Biological Chemistry*, **113,** (3), April, 1936. The preparation of cupric selenite is described in the *Journal of the American Chemical Society*, **52,** 3881 (1930).

SOAP BOILING *on a* LABORATORY SCALE

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THE preparation of cold process soap on a small scale has been described in the literature[1] and there have been numerous discussions[2] of soap boiling as commonly carried out in industry. Reduction in scale from the huge kettle of the factory to the one-pound kettle of the laboratory is not simple, however, and descriptions of procedure and apparatus suitable for the latter have been lacking. The result is that soap-boiling experiments are seldom attempted in school and college chemistry courses, although such experiments would be both interesting and instructive additions to laboratory training. The following paper is an attempt to rectify this situation, for neither is the requisite apparatus costly nor the technic difficult, and a laboratory product of high quality can be produced.

The common saponification reaction, whereby soap and glycerin are obtained from fat and alkali, is well known:

$$(CH_3(CH_2)_xCOO)_3\,C_3H_5 + 3NaOH \longrightarrow 3CH_3(CH_2)_x\,COONa + C_3H_5(OH)_3$$

Despite the simplicity of this equation, soap boiling demands more than mere mixing of the two ingredients. The first difficulty is that of initiating the reaction; once started, it becomes practically autocatalytic. Emulsification of the oil and alkali is essential at the beginning in order to multiply the area of contact between the two, since the initial reaction takes place at this interface. However, the soap formed plays a more important role than that of a mere emulsifying agent; it acts as a mutual solvent for both oil and alkali, and the chief reaction of the two takes place in this solvent medium.[3] The accomplishment of this reaction is the first step in the soap-making process. Thereafter, purification is the object, and to this end changes in phase are brought about by varying the proportions of soap, electrolyte, and water. For a full understanding of the physical chemistry involved in these phase changes, the student is referred in particular to the numerous articles on the subject[4] by J. W. McBain and his students and by R. H. Ferguson, *et al.*

Briefly summarized, the first step in soap making consists in boiling oil or fat with slowly increasing amounts of sodium hydroxide solution, maintaining at all times the proper strength of alkali. The reaction then proceeds to practical completion, and further addition of alkali (or of NaCl) beyond this point throws the soap out of solution, or "grains" it. The soap rises to the top as a separate layer, below which lies an aqueous layer which contains almost no soap, but most of the glycerin, electrolyte, and water-soluble impurities. This aqueous layer is withdrawn, and the remaining soap is boiled again either with strong alkali, to insure saponification of the last traces of oil, or with salt brine, to wash out excess alkali, which would be objectionable in the finished soap. After each caustic or salt wash, the contents of the kettle are allowed to stand (hot) while stratification occurs, and the aqueous layer is removed and discarded.

The final purification step is variously known as *pitching*, *fitting*, or *settling*. When the overall contents of a kettle of tallow soap consists of approximately 50% soap, 1.5% salt, and 48.5% water, a separation into two distinct and immiscible liquid phases occurs, or even three phases when a little more salt is added. These phases are:

(*a*) *Neat soap*, an anisotropic phase constituting 60–80% of the total and consisting of some 66–68% soap, 30–33% water, and 1–2% electrolyte, glycerin, unsaponifiable organic matter, etc. This is the phase which, on cooling and solidifying or drying, gives the usual soaps of commerce.

(*b*) *Nigre*, an isotropic solution of soap in salt water, the soap concentration varying widely but being usually around 20–40% and the salt content some 4–6%. In industry, this nigre, which is high in impurities, is reworked with soap of a lower grade.

(*c*) *Soap lye*, or *pitchwater*, a salt solution practically free from soap.

Pitching consists in adjusting concentrations in the kettle so that the first two, and preferably also the third, of these phases shall separate into layers. The top layer only, which is *neat soap*, is saved.

It is possible to saponify the oil with such a small

[1] EVANS, "Experimental soap making," J. CHEM. EDUC., **14**, 534–6 (1937).

[2] For example, MCBAIN AND WALLS, "Colloid chemistry of soap. Part II. The soap boiling process," Fourth report of colloid chemistry and its general and industrial applications, London, **1927**, pp. 244–63; PRESTON, "The modern soap industry," J. CHEM. EDUC., **2**, 1035–44 (1925); and WEBB, "Soap and glycerine manufacture," Davis Bros., London, **1927**, 224 pp.

[3] SMITH, "The kinetics of soap making," *J. Soc. Chem. Ind.*, **51**, 337–48T (1932).

[4] For example, MCBAIN AND WALLS, *loc. cit.*, and FERGUSON, "Phase phenomena in commercial soap systems," *Oil and Soap*, **9**, 5–8 and 25 (1932).

excess of alkali that one can "drop a nigre" at once, without intermediate treatments with lye or salt brine, but it is customary to grain with salt at the end of the saponification and to "wash" at least once each with strong caustic and with salt brine before proceeding to the *pitch*. More detailed instructions for carrying out these steps will be given below.

APPARATUS REQUIRED FOR LABORATORY SOAP BOILING

The essential equipment consists of a steam line and a vessel which permits stratification and separation of hot, and often viscous, liquid layers. No mechanical or manual stirring is required, since this can be accomplished by steam alone. Figure 1 shows a simple assembly suitable for work upon a one-pound scale. The soap kettle can be made from a 3-liter pyrex Erlenmeyer flask, the neck of which has been sealed as shown, while a hole three or four inches in diameter is cut in its bottom. The need for sturdier and larger kettles than those of this type led this laboratory 14 or 15 years ago to have 12-liter kettles of thick pyrex glass molded to order, but more recently, conical pyrex "percolators" have become commercially available,[5] and these make satisfactory kettles, whether in the 2-, 4- or 8-liter size. The kettle can be fitted with a collar and hung from a support above. In the case of the larger "percolators," a rope and pulley will be found convenient for lifting from and lowering into the water bath.

Temperature control of the hot water bath may be as desired, but it would be hard to find a more foolproof system than that pictured, namely, steam from the laboratory line bubbling through water at such a rate as to keep the latter boiling. Excess steam escapes into the room, while the combination of condensation and overflow to the drain maintains constant water level. Steam for the kettle itself may be drawn from the laboratory line, or it may be generated as shown. The former method is advised for an 8-liter "percolator," the latter for a one-pound kettle.

When a lower liquid layer is to be drawn off from the kettle, this may be done by suction from the sealed inverted Erlenmeyer, or by gravity from the percolator if rubber tubing, closed by means of a screw clamp, is fitted over the outlet nipple of the latter.

Refinements will occur to the user, but the apparatus just described should be capable of assembly in any laboratory at small expense.

SOAP STOCKS

Kitchen grease, lard, vegetable shortening, olive oil, and salad oils are everywhere available. Beef tallow, coconut oil, and "red oil" (technical oleic acid) can be bought with slightly more difficulty. A 3:1 mixture of unrefined tallow and coconut oil is an ideal stock for a beginner to use.

SOAP-BOILING PROCEDURE

In the laboratory, no attempt need be made to recover the glycerin formed as a by-product, and one can use a large excess of NaOH without qualms as to cost, such as beset the manufacturer. Each type of oil has its own kettle characteristics which can best be learned in the school of experience. No universal law can be laid down as to the proper strength of lye to use or the rate at which it should be added. Each new oil entails a change in technic. Coconut oil soap, for example, is so soluble that unusually strong lyes and brines must be used in handling it, and its rate of saponification (after the initial induction period) is so rapid that only alertness and skill can prevent a boil-over.

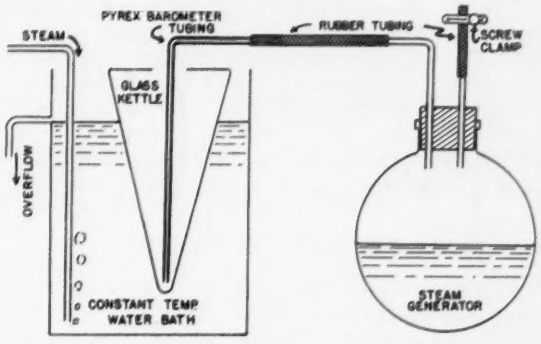

FIGURE 1.—APPARATUS FOR LABORATORY SOAP BOILING

Tallow, on the other hand, saponifies slowly, and relatively low concentrations of electrolyte throw its soap out of solution. A refined tallow, free from fatty acids, is always hard to boil, and if such a soap stock must be used, the addition of a small amount of fatty acid or of powdered soap at the beginning is recommended, to facilitate initial emulsification.

In the description that follows, it will be assumed that a 4-liter pyrex percolator is used as a kettle, and that the soap stock is tallow.

(1) *Saponification*

Charge the kettle with 500 g. of fat and 100 cc. of water. Boil with steam while adding slowly 200 cc. of 15 per cent NaOH solution. This may require half an hour or more. If the lye is added more slowly than necessary, no harm will result, but if it is added too fast, emulsification is interfered with and no saponification occurs. When saponification does begin, thickening takes place, and if a spatula be inserted and withdrawn, a smear of soapy, greasy emulsion remains on it. This state being reached, lye should be added as fast as possible without breaking the emulsion, and a more concentrated solution (28 per cent) should be used. While too rapid addition may still break the emulsion, yet too slow addition will produce *middle soap*, the stiff, gummy soap phase which is the bane of the beginner. The remedy for the former situation is to add water; that for middle soap is prolonged boiling with strong NaOH or NaCl solution.

[5] See laboratory supply house catalogs.

Granted that an emulsion is maintained and middle soap avoided, the soap mass becomes thicker until finally all of the fat has been saponified. There will then be present soap, water, glycerin, and excess NaOH, all forming an apparently homogeneous phase through which steam is being continuously blown. If a spatula be dipped in, a smooth layer of soap should adhere to it; if the hot soap be squeezed between thumb and forefinger, it should solidify to a thin, dry, non-greasy flake; if tasted, there should be an alkali bite, and this bite should not disappear upon further boiling.

If these criteria are met, the saponification is complete and the soap is next "grained out," "salted out," or "opened" by adding more NaOH, or, alternatively, by adding NaCl. Curds of soap, floating on clear lye, result, the sudden heterogeneity being clearly recognizable by eye. Steam is now turned off and the kettle is allowed to stand for 10 minutes. The lower, aqueous layer, called *seat*, is drawn off and discarded (unless glycerin is to be recovered), and the upper, soap layer is ready for the second step.

(2) *Strong Change, or First Lye Wash*

This step may be omitted if the soap boiler is sure that *all* of the fat was saponified in the first step, but to get good results consistently, it is advised that it be included.

Water is added slowly and the soap is "closed," *i. e.*, it is boiled with steam until the curd redissolves to give again a smooth, homogeneous phase. Four hundred cc. of 28 per cent lye are then added, which again grains the soap. After boiling 10 minutes longer, the kettle is allowed to stand for the same length of time, and the seat is drawn off and discarded.

(3) *First Salt Wash*

This step may be omitted if the presence of some free alkali in the finished soap is not objectionable, but unless the oil used is of high grade, one or more lye or salt washes are needed to wash out dirt and colored impurities.

Four hundred cc. of saturated salt solution are boiled through the soap. Then, after a 10-minute stand, the seat is drawn off and discarded.

(4) *First Pitch*

Add water slowly, boiling constantly, until soap curds begin to soften and the soap becomes almost, but not quite, "closed." If too much water is added and the soap does close, it should be "opened" to a soft grain by adding salt. After a 10-minute stand, the seat is drawn off and discarded.

It seems to be legitimate to call this step either a pitch, because water only is added, or a salt wash, because only seat, and no nigre, separates as the second phase. It is not an essential part of the process. Its object is to reduce the electrolyte content so as to avoid the need for an excessive amount of water in the next step.

(5) *Second Pitch*

Add water slowly, while boiling very vigorously, until the soap is somewhat nearer to being "closed" than in the first pitch. When the proportions of soap, water, and electrolyte are correct, small steam bubbles entrapped in the viscous soap cause it to swell to the top of the kettle, if the boiling is sufficiently vigorous. (A lid may be necessary for protection against excessive splashing.) The soap will now slide from a spatula in coherent sheets or flakes, leaving the surface of the spatula clean.[6] If too little water has been added, the curd soap will not adhere to the spatula; if too much, the soap adheres in a smooth layer. In the latter case, more salt brine should be added.

Steam is now cut off and the kettle allowed to stand. A characteristic folding over of the surface of the soap will be observed as the level falls, and dark streaks of nigre can be seen settling in the kettle to form a distinct layer at the bottom. After an hour's stand, the nigre should be from 20–40% of the total volume, but for complete settling at least 16 hours should be allowed for a kettle of the size specified herein.[7]

The nigre is next drawn off and discarded, leaving finished soap in the kettle. This is usually covered with a dry crust, and to avoid mixing this with the neat soap, the latter is drawn off from the bottom into a suitable container in which it is allowed to cool and solidify. Since the resulting cake of "kettle soap" will probably be streaked or mottled in appearance, it is usually "crutched," or stirred thoroughly, while still hot and molten. A mechanical crutcher, with a hot water jacket, is preferable, but not essential. It is here that perfume, coloring matter, sodium silicate, etc., may be mixed in, if desired, or air beaten in if a floating soap is the aim.

Soap boiling is an art, to be mastered only by practice. The *maestro* then varies his technic to suit the particular requirements of the oil in hand. For example, a fatty acid such as "red oil" combines so rapidly with the added alkali that it is usually advisable to reverse procedure, and add the oil to the alkali. In this way a large excess of electrolyte is assured, which will prevent the formation of middle soap.

Lastly, both beginner and *maestro* have this consolation: So long as they do not boil the soap over the top of the kettle, there is little that they can do that will ruin it, since mistakes are not irrevocable. It is always possible to "open" the soap, drop a "seat" and discard it, and start over again.

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[6] WEBB, *loc. cit.*, gives photographs of the appearance of soap upon a trowel at various degrees of "openness."

[7] In addition to neat and nigre phases, pitching often does and should result also in a third phase, a clear lye which underlies the nigre. Study of the phase diagram of the system (for example, VOLD AND FERGUSON, "A phase study of the system sodium palmitate-sodium chloride-water at 90°C.," *J. Am. Chem. Soc.*, **60**, 2066–76 (1938), Figure 6 especially) will elucidate this and other phase changes which occur during soap boiling.

SUBJECT MATTER *of a* COURSE *in* UNIT PROCESSES[1]

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IT WILL probably never be possible to teach an adequate course in unit processes to undergraduate chemical engineers. The major objective of such a course in unit operations should be a thorough understanding of the fundamental factors involved in the *design* of equipment. In the unit operations course, this involves calculations of fluid flow, pressure drop, area of heat transfer surfaces, proper provision for material transfer, etc. The course in unit processes should be of a similar nature.

However, the fact that a chemical reaction is taking place in the unit process equipment complicates design and requires considerable knowledge of reaction kinetics. Time is not available in the average four-year undergraduate course for a detailed study of this nature. Even if the student had this knowledge, the time necessary for even simple design problems would be such as to prohibit the study of more than a very few unit processes.

Accordingly, it seems preferable to combine the unit processes course with courses in technology or industrial organic chemistry. The resultant course will then serve to integrate the student's previous knowledge of organic chemistry, physical chemistry, materials of construction, engineering, and economics into an orderly and usable entity. Instead of studying the organic chemical industries as a series of unrelated plant processes, or at best grouped according to major raw materials or chemical types, they may be presented according to the fundamental unit process involved. The value of such an approach is obvious. There is a considerably closer relationship between various halogenation processes, for example, than between the several processes of glycerin manufacture, even though the latter may be more closely knit economically.

The purpose of this paper is to present the author's view of a satisfactory division of the subject matter of an organic chemical technology course according to the various unit processes. An outline of such a course follows. No attempt will be made to give a detailed outline of the method of presentation of each unit process. At the Cambridge, Massachusetts, meeting of the S. P. E. E. in June, 1937, the author presented his views on the satisfactory presentation of one unit process, thermal decomposition (published in the June, 1939, issue of the JOURNAL OF CHEMICAL EDUCATION). A similar presentation is adaptable to the other unit processes.

A general outline of the method of treating the individual unit process is as follows:

1. Chemistry
2. Effect of common variables (time, temperature, pressure, concentration, catalysis)
3. Design of equipment, including unit operations involved and materials of construction
4. *Brief* description of technical processes
   - (*a*) Flowsheet
   - (*b*) By-product utilization or waste disposal
   - (*c*) Hazards of manufacture
   - (*d*) Economic considerations (competing raw materials, competing processes, and competing products)

SUBJECT OUTLINE

I. Thermal decomposition (pyrolysis)
- (*a*) Chemistry
- (*b*) Coal and coal tar
- (*c*) Wood
- (*d*) Petroleum
  - (1) Refining processes
  - (2) Cracking and polymerization
  - (3) Lubricating oil and wax
- (*e*) Miscellaneous (diphenyl, ketene, iso-octane, etc.)

II. Oxidation
- (*a*) Chemistry
- (*b*) Chemical oxidation
  - (1) Saccharin
  - (2) Vanillin
  - (3) Quinoline
- (*c*) Catalytic air oxidation
  1. Acetic acid from acetaldehyde
  2. Formaldehyde from methanol
  3. Oxidation of aliphatic hydrocarbons
  4. Maleic acid from benzene and phthalic anhydride from naphthalene

III. Fermentation
- (*a*) Mechanism
- (*b*) Industrial alcohol
- (*c*) Beer, wine, and distilled liquors
- (*d*) Acetone and butanol
- (*e*) Organic acids
- (*f*) Miscellaneous

IV. Hydrogenation
- (*a*) Chemistry
- (*b*) Hydrogenation of vegetable oils, including other oil refining processes
- (*c*) Fatty acids to alcohols
- (*d*) Synthetic methanol and other alcohols from CO and H_2
- (*e*) Hydrogenolysis of coal, petroleum, and tar
- (*f*) Hydrogenation of aromatic hydrocarbons
- (*g*) Electrolytic reduction

V. Halogenation
- (*a*) Chemistry

[1] Presented before the Second Summer School for Chemical Engineering Teachers sponsored by the Chemical Engineering Division of the Society for the Promotion of Engineering Education at State College, Pennsylvania, June 22, 1939.

(*b*) Chlorination of pentane
(*c*) Chlorination of ethylene and propylene
(*d*) Miscellaneous chlorinations (chloral, chloracetic acid, chlorobenzene, chlorodiphenyl, etc.)
(*e*) War gases

VI. Hydrolysis
(*a*) Chemistry
(*b*) Amyl alcohols
(*c*) Phenol and naphthols
(*d*) Ethylene glycol and glycerin
(*e*) Soap, glycerol and fatty acids
(*f*) Starches and sugars
(1) Saccharification of cellulose
(2) Corn starch and dextrose (and corn refining industry)
(3) Cane and beet sugar
(*g*) Furfural
(*h*) Hydration of olefins and acetylene
(*i*) Miscellaneous (benzoyl chloride, ethylene dichloride, butyl chloride, etc.)

VII. Esterification
(*a*) Chemistry
(*b*) Esters for lacquer solvents
(*c*) "Nitroglycerin" and other explosives
(*d*) Cellulose esters
(1) Lacquers
(*e*) Rayon
(*f*) Miscellaneous

VIII. Polymerization
(*a*) Chemistry
(*b*) Synthetic resins and other plastics
(*c*) Varnishes
(*d*) "Synthetic" rubber (compounding of natural rubber could be included)

IX. Nitration

X. Amination
(*a*) By reduction
(*b*) By ammonolysis
(1) Aniline and *p*-nitroaniline

XI. Sulfonation
(*a*) Sulfonic acids
(*b*) Sulfonated fatty acids
(*c*) Other detergents

XII. Diazotization
(*a*) Chemistry
(*b*) Dyes

XIII. Friedel-Crafts reaction

DISCUSSION OF OUTLINE

The sequence of the various unit processes differs from that of most comparable courses at the present time. This sequence is, however, not entirely arbitrary but is based on a logical method of presentation.

Thermal decomposition or pyrolysis is chosen as the first unit process for the following reasons: First, it illustrates the unit process approach by showing the similarities between three otherwise unrelated industries—coal carbonization, wood distillation, and the cracking of petroleum. Second, it deals chiefly with very common and abundant raw materials. Third, in studying the chemistry of pyrolysis at the beginning of the course a great deal of repetition is avoided in studying other unit processes, since pyrolytic reactions accompany nearly all organic reactions at elevated temperatures.

Many things can be pointed out concerning the arrangement of the various unit processes in the course. Briefly some of the more important ones are mentioned here.

In the section on the cracking of petroleum, polymerization of olefins is included, since it is more closely related to pyrolysis than to other polymerization processes. The same holds true for the more recent alkylation processes of reacting olefins with paraffin hydrocarbons. During this same study of cracking, refining processes of the petroleum industry in general are taken up just as in the usual technology course.

Oxidation is the second unit process considered because of the common effects of air and other oxidizing agents in various unit processes.

The third unit process, fermentation, may be open to some argument since the various bacterial and enzymatic processes may also be treated under other headings. For example, alcohol to acetic acid may be classed as oxidation, and the enzymatic inversion of sucrose is certainly hydrolysis. However, the problems incidental to fermentation processes are considerably different from those of other unit processes and merit special study. In general, the average chemical engineer has practically no knowledge of the actions of molds, yeasts, and bacteria. A thorough consideration of the control necessary for such processes is time well spent, and is better understood when all industrial fermentation processes are studied at the same time. In the same way, a brief treatment of the changes taking place during the malting of barley preparatory to beer manufacture aids in the consideration of other processes where various grains are used as raw materials.

Under halogenation, war gases are considered, since most of them are halogen-containing compounds. The unit process halogenation is followed immediately by hydrolysis, since practically all industrial chlorinated products are hydrolyzed to more valuable substances. Examples are: (1) chlorination of pentane followed by hydrolysis to amyl alcohols, (2) chlorination of ethylene followed by hydrolysis to ethylene glycol, (3) chlorination of benzene followed by hydrolysis to phenol.

Under hydrolysis, the manufacture of soap is considered because of its close relation to the hydrolysis of fats and oils to glycerin and fatty acids. Also included under hydrolysis is the conversion of starch to syrup and dextrose. This is a good time to introduce the starch industry and the manufacture of cane and beet sugars.

Under esterification, after studying solvent esters and cellulose nitrate, the lacquer industry is taken up. The rayon industry falls into line just after this, even though some rayon processes do not involve esterification.

Dye manufacture is treated at the end of the course after nitration, sulfonation, alkylation, and diazotization have been studied.

Naturally, a certain amount of overlapping is inevitable in a course which is so all-inclusive. Under this outline the chief overlapping factors are economic ones, and certainly these deserve emphasis in any course dealing with the chemical industry.

RADIOACTIVITY *and the* PERIODIC TABLE[1]

An Introduction to the Study of Atomic Structure and Isotopes in Elementary Chemistry

J. F. KING AND P. H. FALL[2]

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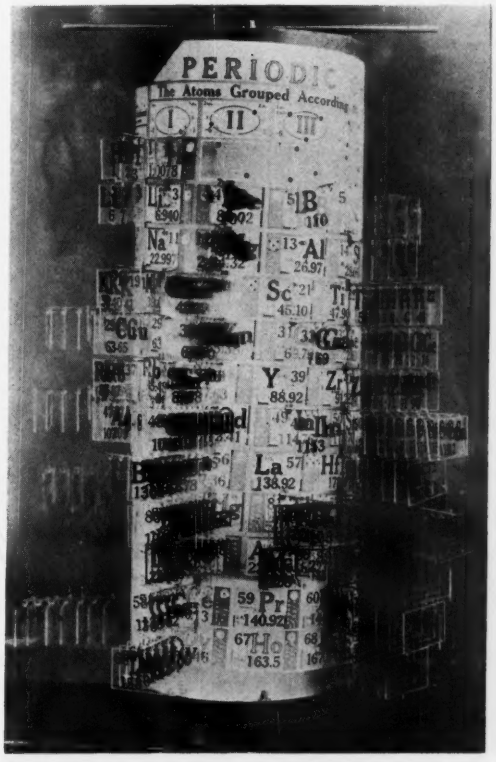
IN AN elementary course in chemistry, radioactivity and the periodic table serve as an excellent introduction to a study of the modern theory of atomic structure. The historical development of radioactivity, including an understanding of the Soddy-Fajans Disintegration Hypothesis, "catalyzes" the student's grasp or understanding of the concepts of atomic structure, atomic numbers, mass numbers, and isotopes. The contributions which Rutherford and his school of workers made to the rapid evolution of the modern theories of atomic structure are delightfully revealed in a most illuminating way in the excellent biography of Rutherford.[3] Any instructor will find it both stimulating and helpful to review in his class these contributions and developments when taking up the subject of atomic structure, isotopes and the periodic table. Once the student has grasped the significance of the Soddy-Fajans Disintegration Hypothesis, his "feeling" for atomic weights, atomic numbers, mass numbers, and isotopes becomes sufficiently definite to go into some of the details of the periodic table.

In order to show the students in our department how the forty naturally occurring radioactive isotopes, as well as the 263 known stable isotopes, fit into the periodic table, we have worked out an adaptation of a commonly used periodic chart of the elements. A great many charts have been proposed to illustrate how the loss of an alpha particle lowers the atomic number two units, whereas the loss of a beta particle raises the atomic number one unit. In the first case above, the disintegration product falls into the periodic group two units to the left of its immediate ancestor, whereas the disintegration product resulting from the loss of a beta particle falls into a periodic group one unit to the right of its immediate ancestor. This is really the Soddy-Fajans Rule. Some charts have Group zero elements in the middle but it has been our experience that such a chart confuses the student because it is so different from the periodic chart with which he is usually somewhat familiar.

In order to utilize the usual group arrangement, a Hubbard-designed Periodic Chart[4] was glued to a rotatable galvanized iron (20-gage) drum, 16″ in diameter and 43″ high. As the accompanying two photographs show, the chart was mounted on the drum so that there



is a regular change in atomic number as the drum is rotated. The spiral-like arrangement of the originally rectangular chart was easily realized by joining the lower left edge of row (period) 1 to the upper right edge of row (period) 2, and so on down the entire horizontal rows, when the left and right edges of the rectangular chart were joined together on the cylindrical drum.

[1] Presented before the Division of Chemical Education at the ninety-ninth meeting of the A. C. S. in Cincinnati, Ohio, April 8–12, 1940.

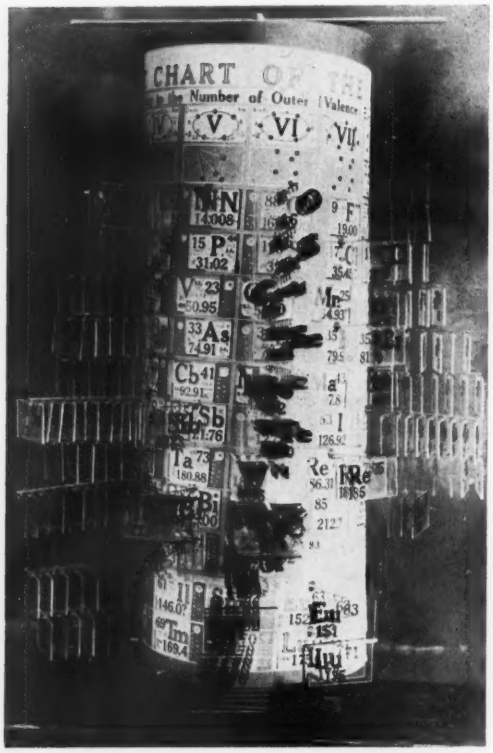
[2] Present address: Hiram College, Hiram, Ohio.

[3] EVE, "Rutherford," The Macmillan Company, New York City, 1939.

[4] Published by W. M. Welch Manufacturing Company, Chicago, Illinois.

The chart was glued to the drum by means of a thin film of regular furniture glue.

At the upper edge of the space allotted to each element which has any known isotopes, was fastened, by means of a small brass hinge, a rectangular brass rod, $1/4''$ wide and approximately $1/16''$ thick. To each separate rod were attached small cup hooks—the number of hooks corresponding to the number of published[5] isotopes of the particular element. In each case the length of the rod attached depended upon the number of hooks to be fastened to it. The hooks were spaced an inch apart on each rod. From these hooks can be suspended, by means of small holes, lucite rectangles ($2\frac{1}{2}'' \times 4\frac{1}{2}'' \times 1/8''$) on which are printed the symbols, atomic numbers, and mass numbers of all the isotopic species of the elements. The atomic numbers are printed in red (using Duco lacquer, Mansion Maroon, 246-52926) and the mass numbers, as well as the symbols, are in black (using Duco lacquer, 246-2048-R). On each of the lucite plates of the 263 known stable isotopes there is also given the per cent abundance of the particular isotope. This is printed with India ink on a small strip of scotch cellulose tape placed under the mass number. Similarly, on each of the lucite plates of the forty naturally occurring radioactive isotopes, the "half-life" of the particular radioactive isotope is printed on a small strip of scotch tape. Furthermore, on each of these plates is indicated the immediate ancestor of the particular radioactive isotope and also the immediate descendant of this isotope, as well as the rays given off in the formation and in the disintegration of the particular radioactive isotope. An example of a lucite plate for a radioactive isotope is given in the accompanying diagram.



As a further aid in observing or "spotting" the radioactive isotopes, when all the stable and naturally occurring radioactive isotopes are hung on their appropriate hooks (making a total of 303 plates on the chart), the upper and the left-hand borders of the plates designating the naturally occurring radioactive isotopes are painted red. This border is visible in the accompanying photographs.

It is a simple matter to follow through the disintegration of an entire "family" of any of the three radioactive series. This is done by placing on their proper hooks the lucite plates, one by one, as we follow through the disintegration series. By such a procedure the student can readily observe thes hifting of the elements, in the periodic group, resulting from a loss of an alpha particle or the loss of a beta particle. Furthermore with this type of chart it is easy for the student to see that any one of the respective disintegration products of a radioactive element is an isotope of an element normally listed in the periodic table. This we find highly advantageous.

LUCITE PLATE FOR A RADIOACTIVE ISOTOPE

We have found this demonstration model to be of great value, not only in clarifying the points already indicated, but also in making evident, even to the casual observer of the assembled chart, the relative numbers of isotopes of the different elements, as well as the abundance of isotopes in the even-numbered periodic groups and the scarcity of isotopes in the odd-numbered periodic groups. This is very apparent from the illustrations.

[5] LIVINGOOD AND SEABORG, *Rev. Mod. Phys.*, **12**, 30 (1940).

SELENIUM—*the* NEW ENIGMA

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SELENIUM researches have had a new impetus during the past decade resulting in many new uses, and bizarre compounds. Some of the recently developed uses are the manufacture of photo-electric cells, fire-proof cable coverings, abrasive resistant rubber, and as a dehydrogenating agent. Organic compounds of selenium have been prepared from this element which are truly unusual in both character and odor. A comprehensive review of these compounds by W. F. Bradt (*1*) reveals that although a great deal of work has been done in this direction we are in need of some thoroughgoing research really to understand the chemistry of selenium when held in organic union.

In this article we will not attempt to survey the inorganic or organic chemistry of this element; but we will review a small segment of the biological researches which, we believe, are quite significant. Indeed, medical men have, as a result of these researches, come to suspect that the disease pellagra is nothing more than selenium poisoning.

Selenium poisoning of animals has been known as "alkali poisoning" or "blind staggers." This disease seems to be purely a local occurrence in the North Central and Great Plains States; in Kansas the disease was described by Mayo (*2*) as early as 1890–1891. Studies by Hurd-Karrer (*3*) on the effect of vegetation grown in seleniferous soils on animals have cleared the situation a great deal. Her researches prove that plants grown in soils containing one to two parts per million of selenium (as selenate; for the selenites are reduced by the plant, and red selenium may be seen in root tissue) have all the vigor and height of the normal species, but when fed to rats are decidedly toxic; analysis on these plants shows as much as three hundred twenty-five to three hundred thirty parts per million of selenium in the leafy tissue. However, when the same plants were grown in the same type of seleniferous soils, but made rich with sulfur, no ill effects were noticed. Hurd-Karrer, therefore, suggests a selenium-sulfur relationship to the effect that vegetation (cabbage, broccoli, mustard, and cauliflower) which requires a large amount of sulfur, when grown in soils which are low in sulfur content will take up selenium to compensate for the deficiency even to the extent of becoming toxic. Plants which require little sulfur, such as grasses, may be grown in sulfur-poor soil and will not be toxic unless the selenium content (as selenate) of the soil is exceptionally high. An interesting item is the fact that it appears to be young plants which absorb the most selenium, and toward maturity the content of this element in the leafy tissue is appreciably decreased; this is true especially in the case of wheat. Young wheat growing in soil containing thirty parts per million sodium selenate had as high as 1120 parts per million in the leafy tissue. However, upon maturity the same plants had only two hundred twenty parts per million. Another interesting fact is that when wheat is infested with plant lice, and the roots are treated with sodium selenate solution, the lice immediately decamp.

Wheat is one of the cereals which is particularly susceptible to selenium poisoning. Indeed, Robinson (*4*) is of the opinion that no wheat is absolutely free of this substance. His researches indicate that commercial wheat contains from one to nineteen parts per million, and that most of the element is concentrated in the gluten of the cereal. A sample of flour purchased in New York had a content as high as twenty-six parts per million, which was definitely harmful; for he sets sixteen parts per million as the maximum amount of selenium which can occur in a substance without harmful results to the human body.

The symptomology of animals which have been poisoned by selenized vegetation is described (*5*) as:

(1) Necrosis and regeneration of hepatic parenchyma with periportal fibrosis and resulting cirrhosis combined with hemorrhages and secondary inflammatory reaction of lungs and kidneys.

(2) Reduced selenium is found in the liver and spleen, and compounds of selenium are found in all tissues, secretions, and excretions.

(3) Cattle, sheep, horses, and pigs show erosions on the ends of the weight-bearing bones, along with hoof abnormalities which impair locomotion, malaise, anorexia, stunted growth, loss of hair, loss of weight and emaciation, impairment of reproductive power, and severe anemia to be followed by exhaustion, toxemia, and death.

(4) Chickens (*6*) show a decided impairment of fertility; if the eggs hatch, the young do not live long, and monstrosities occur among them frequently.

Known cases of human poisoning by seleniferous foods have been studied by Smith, Franke, and Westfall (*7*). These cases were one hundred eleven families of the Wyoming, South Dakota, and Nebraska area; and their observations on the symptomology of selenium toxicosis were almost identical with the symptomology of pellagra as set forth by Rohan De Barondes (*8*) in his study of selenium poisoning, which are:

(1) Gastro-intestinal disturbances and nervous and mental disorders that often terminate in complete dementia.

(2) On exposure to the bright light of sun during summer months, skin manifestations present themselves in the form of vesiculations and actinic dermatitis. The other symptoms present become more aggravated, and it is at this time that the mortality is highest.

(3) During the fall months the skin commences to desquamate, and by wintertime atrophic and pigmented areas resembling vitiligo make their appearance.

(4) Patients of pellagra complain of a garlic-like odor, or an arsenic-like odor in the mouth and breath. A similar odor is noted on and about selenium poisoned animals.

De Barondes elaborates upon his study of selenium poisoning to remark that selenium alkalis and oxides are toxic, but the oxides if taken orally in small quantities seem to contribute to the oxidation of body sulfur. It is used for this reason in the treatment of cancer.

A comparison of the symptoms of pellagra have been observed in alcoholic patients who drink cheap beverages made of corn, probably containing much selenium. The proper treatment for selenium toxicosis is a sulfur-rich diet and dried yeast. W. H. Sebrell (*9*) gives as the proper diet for pellagra, dried yeast, lean meats, wheat-germ containing foods, and sulfur-bearing green vegetables. Again, there is a similarity, even in the treatment for the two diseases.

These few excerpts from biological researches make the selenium problem very personal to all branches of chemistry, and it is not only an enigma to the inorganic and organic chemist, but also to the physician and the agricultural chemist.

DEFINITIONS OF SOME OF THE MEDICAL TERMS

(1) *Necrosis.*—Death of more or less extensive groups of cells with regenerative changes.
(2) *Hepatic Parenchyma.*—Inflammation of liver, may be acute yellow atrophy of organ.
(3) *Periportal Fibrosis.*—Fibrosis of tissue around the liver; fibrosis-forming of fibers.
(4) *Cirrhosis.*—A degeneration or atrophy of parenchyma cells of an organ.
(5) *Malaise.*—Discomfort, out-of-sorts feeling.
(6) *Anorexia.*—Loss of appetite.
(7) *Vesiculations.*—Inflations, inflamed swollen spots.
(8) *Actinic Dermatitis.*—Inflammation of skin due to effects of sunlight.
(9) *Desquamation.*—Shredding, peeling, or scaling of skin.
(10) *Atrophic.*—Wasted areas.
(11) *Regeneration.*—Reproduction, or repair of injured tissue.

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AN INEXPENSIVE POWER UNIT FOR HIGH-VOLTAGE DIRECT CURRENT

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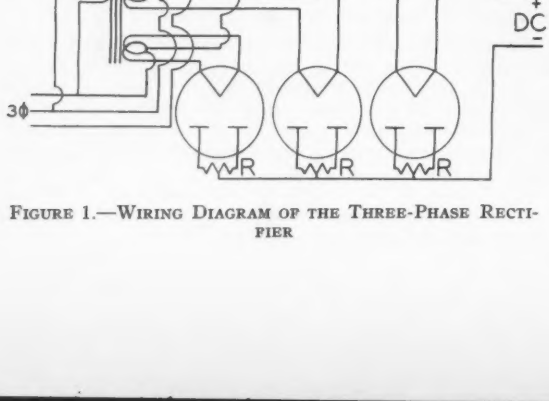

FIGURE 1.—WIRING DIAGRAM OF THE THREE-PHASE RECTIFIER

ALTHOUGH it is convenient to have in the laboratory direct current of two or three hundred volts, few schools are thus equipped, presumably because of the common belief that an expensive motor generator is required. For some time the authors have been operating a high-pressure mercury arc requiring this voltage range with the aid of direct current furnished by a three-phase rectifier constructed, for the most part, from standard and relatively inexpensive electrical supplies. This power unit has given excellent service and a description of it is presented herewith, in the belief that it will be of use to teachers and experimenters in many fields who do not have ready access to high-voltage direct current but do have three-phase alternating current.

Figure 1 is an electrical diagram of the equipment. *T* is a transformer designed for 240 volts primary and having three 5-volt-3-ampere and one 5-volt-9-ampere

center tap secondaries with 1000 volts insulation between windings and above ground. The rectifier tubes are standard type 83. The plates of each of these are connected to 10-ohm-10-watt center tapped resistors, *R*, as indicated. The filaments of the upper three tubes in the diagram operate on the 5-volt-9-ampere secondary, while the lower three have their filaments heated from individual 5-volt-3-ampere secondaries. *Ch* is a choke of 1500 turns of No. 16 cotton enamel copper wire on a laminated iron core of approximately six square inches in cross section and with an air gap of about 2 mm. *F* is a 3-ampere fuse.

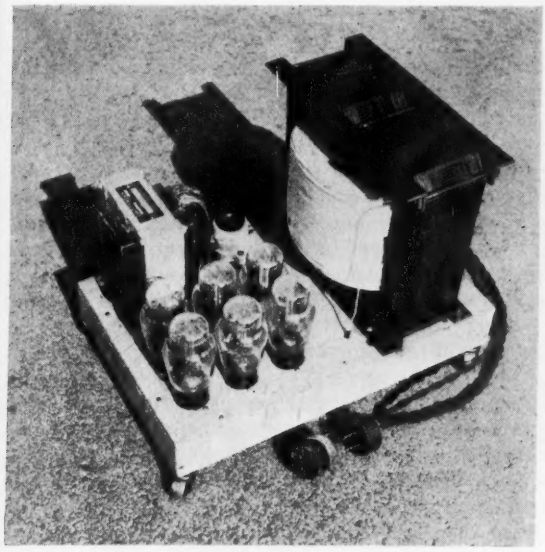

FIGURE 2.—PHOTOGRAPH OF THE THREE-PHASE RECTIFIER

Figure 2 is a photograph of the complete apparatus showing transformer, rectifier tubes, fuse, choke, and leads for direct current and for three-phase alternating current. The three-ply wood base is 10 inches wide and 15 inches in length. The resistors and connecting wires are all beneath this board and are readily accessible by turning the complete unit on its side.

Operating on 240 volts, three-phase A.C., this setup gives approximately 270 volts D.C. with a load of 2.5 amperes. The no-load voltage is slightly over 300. In our laboratory this apparatus has been used for over 900 hours to carry a 2.5-ampere mercury arc load and the tubes are still performing perfectly. The tubes are the only parts which will deteriorate appreciably with time and our experience indicates that the upkeep on these will not exceed one-third of a cent per hour and may become considerably less than this amount. This is true in spite of the fact that 2.5 amperes are being used, and consequently each tube is continuously passing slightly more than its rated peak load of 0.8 ampere.

In order to determine the amount of ripple in the D.C. output, cathode ray oscillograms of current were taken[1] and compared with known alternating current as shown in Figure 3. Number 1 is a reference oscillogram of 0.061 ampere operating on 60 cycles A.C. In comparison to this, No. 2 shows the *fluctuations* in 2.50 amperes D.C. from the rectifier, operating a mercury arc load. From the heights of the waves and the currents involved, it can be shown by simple computations that the maximum deviation from 2.50 amperes is plus and minus 0.015 ampere.

The 3-ampere fuse is a necessary protection for the tubes against accidental overloading. In our mercury arc circuit, where variable resistance is eliminated as the arc strikes and increases in length, we have a simple magnetic switch in the D.C. circuit to prevent heavy overload of the rectifier should the arc go out. In any use of this power unit it is important that some type of switch be present in the circuit so that the load is not applied to the rectifier until the tube filaments have had the opportunity to become hot. The purpose of the choke is to smooth the D.C. current and to reduce the peak currents through the tubes; thus the dimensions of the choke described here are not critical and considerable variation is allowable without materially affecting operation.

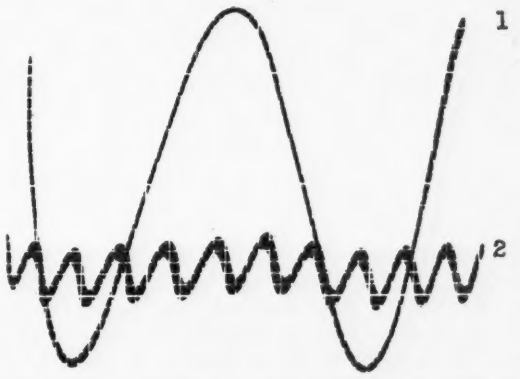

FIGURE 3.—CATHODE RAY OSCILLOGRAMS OF CURRENT

No. 1 is a comparison standard produced by 0.061 amperes of 60 cycle A.C. No. 2 is the ripple component of the D.C. when delivering 2.50 amperes to the mercury arc load

It should be pointed out that the voltage of a rectifier of this general type may be changed by placing suitable transformers in the three-phase circuit, and the current output may be approximately doubled by using twice the number of tubes, etc. In our laboratory this apparatus has been used only to run a mercury arc, but there appears to be no good reason why it should not be employed to supply direct current for electromagnets, lecture experiments, and perhaps many other purposes.

[1] The authors are grateful to Mr. Leo Delsasso of the Physics Department of the University of California for assistance in taking the oscillograms.

NEW TRENDS *in* CHEMISTRY COURSES *for* TEACHERS' COLLEGES

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TEACHERS' colleges in general as well as many courses of study offered by them have received considerable criticism in recent years, by other colleges and universities, as being "soft," offering improperly taught subjects with antiquated ideas, and weak with regard to the training of students desiring to enter professions other than teaching.

With the majority of teachers' colleges today offering courses of study for pre-professional students, regular A.B. and B.S. degrees, two-year work for those desiring to finish in larger institutions, along with the regular teacher training curriculum, considerable attention is now given to correcting any weaknesses. No longer is the teachers' college graduate looked upon as the "weaker" brother. Their graduates are taking responsible positions in research, industry, and business. This is due chiefly to newer trends that are rapidly being adopted in many schools of this type.

The author made a recent investigation into present courses of study offered by several leading teachers' colleges in the field of progressive education, and finds courses of study in chemistry comparable to those given in any larger institution of learning.

One of the newer courses found to be taught is that of semimicro qualitative analysis, which replaces the old orthodox tedious "qual" of yesteryear. It has been found that for colleges having a limited budget, especially with the perennial increase in student ranks, the semimicro technic is ideal. It is in line with modern trends of analytical procedure, and requires a minimum in reagents, space, expense, and most of all, time to the student. The old laborious routine is supplanted by a rapid technic of separation which the student completes in record time, some of the more capable students being able to run a "complete analysis" in one laboratory period, with a greater percentage of efficiency. Many organic reagents are employed, and all the modern theories of solubility are clearly illustrated. Spot testing lends to the fascination of the course to capture and hold the students' interest. The prospective teacher is thereby trained better to guide his high-school charges in their choice of a vocation.

Other courses, now being offered, give training in physical chemistry, colloidal chemistry, and organic synthesis with ultimate analysis.

In the latter course, which is now being taught regularly to students desiring to major in chemistry, seeking a study in the application of basic principles, organic synthesis and analysis offer an excellent panacea. In this course the latest theoretical principles, both in qualitative and quantitative organic analysis, are studied along with advanced technic in synthesis. A complete laboratory outline is designed to cover the entire field of organic combustions. Library and reference work also makes up an interesting phase of the course.

The equipment is rather expensive, but this is offset by the valuable training offered. Synthesis, decomposition, oxidation, reduction, solvation, molecular weights, absorption, dehydration, catalysts, along with careful technic in weighing and manipulation, in one course, offers the student training comparable to any which he might secure in a regular arts and science college or university.

For all those who plan to teach science in the elementary or secondary schools, courses in physical science are required. It is noted that here the teachers' colleges lead the way. The importance of this type of course is emphasized by the fact that the American Association for the Advancement of Science appointed a committee, known as the Committee for the Improvement of Science in General Education, with Furvas, Gordon, Johnson, and Smith as committee members for the chemistry division. Grants-in-aid have been established to stimulate work in this rapidly growing field of science. These courses correlate physics, chemistry, and biology with the home and home life. This equips the prospective teacher with material to help the students reach a better solution of their everyday problems of clocks, electric irons, washing machines, radios, gardening, cooking, and so forth, in the home.

Besides these newer courses, regular training is given in general, quantitative, and organic chemistry, and in the history of chemistry. No longer do teachers' colleges bring up the rear in training, but today we find the majority in step with all recent advances in chemical education.

"Unlike the pioneer, the research worker cannot hope to reach the golden west and rest from his labors with his task accomplished. The frontier of research is boundless—a magic casement, opening on the foam of perilous seas."

« « « HIGH-SCHOOL NOTES » » »

MODERN CHEMICAL CONCEPTS AND THE HIGH-SCHOOL CURRICULUM

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THE purpose of this article is to present, for high-school use, some of the available theoretical and experimental material dealing with three of the fundamental chemical concepts. The concepts that will be considered are (1) the electronic theory of matter, (2) the interionic attraction theory of strong electrolytes, and (3) the Brønsted-Lowry acid-base theory.

It is characteristic of science to attempt to present intellectual concepts to pupils in what is considered the most correct form at the present time. It is mainly on this basis that we should attempt the presentation to our pupils. Theoretical material of this sort is stimulating to pupil imagination and furnishes splendid material and opportunity for the teaching of scientific attitudes and methods. This teaching, however, must be done on such a level that it helps in the growth of the pupil's conceptual mass without imposing too drastic an increase in the quantity of subject matter. There is no doubt that these concepts present difficulties in presentation and comprehension. It is hoped that the material herein presented will decrease these difficulties.

An analysis of the more recent high-school texts shows that in many instances these newer concepts are treated somewhat extensively. The texts considered are listed in Table 1, and the extent of treatment indicated.

TABLE 1

	Treatment		
Text	*Electronic theory Neutron and positron*	*Interionic theory*	*Brønsted theory*
Book 1 (1934)	None	None	None
Book 2 (1935)	Extensive	Moderate	Moderate
Book 3 (1938)	None	None	None
Book 4 (1937)	Moderate	None	None
Book 5 (1937)	Extensive	None	None
Book 6 (1939)	Extensive	Moderate	Slight
Book 7 (1938)	Extensive	Extensive	Slight
Book 8 (1939)	Extensive	Moderate	None

Book 3 is an historical introductory treatment of chemistry, and the electronic and ionization theories are not even mentioned. Book 4 is primarily a book on consumer chemistry. Book 1 is slightly out of date. Consideration of the treatment in the other books shows that these concepts are finding their way into the newer high-school texts. In none of these books is any demonstration material suggested. This is particularly true of the interionic and Brønsted theories. This same difficulty is present even in many college texts. Some simple demonstrations are described in this article and may prove helpful where presentation of the concepts is attempted. With the increasing organization of honor schools throughout the country this material may prove very valuable in the curriculum of such schools.

The concepts are discussed under the headings:

(1) The present state of our knowledge.
(2) How much shall we present to high-school pupils and why?
(3) Method of presentation to pupils—demonstration experiments.

I. THE ELECTRONIC THEORY OF MATTER

(*A*) *The Present State of Our Knowledge*

The neutron was discovered by Chadwick (1932) by bombarding beryllium with alpha particles from polonium. The neutrons, emitted as a result of the disintegration, were allowed to strike paraffin and caused the emission of protons which were measured by a Geiger counter. Momentum and energy considerations caused Chadwick to conclude that only a particle of the approximate mass of a proton could cause the emission of protons. The particle that caused these emissions had a great range and was not deflected in an electric or magnetic field. This particle, then, of mass approximately that of a proton, and of neutral charge, was christened the neutron. This particle, as expected, showed no path in a Wilson cloud chamber but its presence was sometimes shown when it struck something, and charged particles resulted with consequent tracks.

The particle has also been produced as the result of artificial disintegrations or transmutations. It is also one of the projectiles used in producing such disintegrations. Fermi used it in this way and also in the production of artificially radioactive materials, which, apparently, were transuranic elements. More recently the neutron has been used in disintegrations that caused the release of large quantities of energy.

Closely allied with the neutron is the positron, which Anderson discovered in the same year, 1932. The study of a cloud track photograph disclosed a particle of the same mass and quantity of charge as the electron but opposite in sign. The presence of a magnetic field causes this particle to move in the opposite direction from an electron and, therefore, it must be opposite in charge. The positron, thus discovered, had been driven out of the nucleus of lead by gamma radiations (photons).

Positrons have since been produced in a variety of ways. The most interesting of these was the one performed by the Joliot-Curies in which energy was changed into matter (the materialization of energy). A gamma particle (photon) was shot into lead, and this particle was transformed into a positron and an electron. It is now possible to change matter into energy and energy into matter.

From the study of artificial disintegrations and radioactivity and the above experiments a proton and neutron are defined as elementary particles in different quantum states. This definition is necessary since it appears that

(1) a neutron → a proton + an electron
(2) a proton → a positron + a neutron

It is not possible, therefore, to say that a neutron is just a combined electron and proton. To further complicate matters new particles like neutrino and antineutrino seem necessary because of momentum and energy considerations. A newer particle, the mesotron, has also been announced recently.

From the study of hyperfine spectral lines and nuclear spin Pauli and Heisenberg have concluded that there are no free electrons in the nucleus of an atom. The nucleus consists of neutrons and protons and not of protons and electrons as was formerly supposed. The mass number of any ϕ isotope is therefore the sum of the number of protons and neutrons.

(*B*) *What Materials Shall We Present to High-school Pupils and Why?*

At the high-school level it seems necessary to discard much of this available material. Neutrino, antineutrino, mesotron, and most energy and momentum considerations come under this classification. The positron might be mentioned as a result of nuclear disintegrations, but since there is no definite information that it actually exists in the ordinary nucleus some complications might arise.

It seems essential to present the following material.

(1) The nucleus first considered as composed of protons and electrons, then later, of protons and neutrons.
(2) Neutrons to be considered as combined protons and electrons.
(3) The atomic number is the number of protons in the nucleus.
(4) The atomic weight is numerically equal to the sum of the number of neutrons and protons.
(5) The neutron weight is about the same as that of a proton, or about the same as the sum of the weights of a proton and electron.
(6) The positron might be mentioned as a result of disintegrations.
(7) Matter-energy and energy-matter transformations, described on a simple basis experimentally, might prove valuable supplementary material.

These ideas should be presented because

(1) They more closely approximate the truth, as known, than our present materials.

(2) They are expedient—too much subject matter cannot be added.

(3) It should be easier to prevent the confusion that exists in the pupil's mind about atomic number and atomic weight. Atomic number is the number of protons experimentally determined by the Moseley method. The difference between the atomic weight (experimentally determined) and the atomic number is equal to the number of neutrons.

(4) Pupil reading in newspapers and scientific magazines will be made easier and give greater reader comprehension. This is especially significant for those pupils whose formal education ends with the high school.

(*C*) *Method of Presentation to Pupils*

This should present little difficulty for these ideas may be included in our regular scheme of presenting the electronic theory without the expenditure of much additional time. A possible presentation is the following.

As a result of the use of the Crookes tube and of other demonstrations, such as a simple voltaic cell (zinc and copper strips in sulfuric acid) hookup with a small electric light bulb; or the fused salt experiment, described later, the pupil arrives at the idea that matter is electrical in nature. By using the magnet with the Crookes tube it is possible for the pupil to see that the deflected light stream must consist of electrically charged matter. Then since atoms are electrically neutral, the number of positively and negatively charged particles must be equal. From the consideration of the fact that many of the atomic weights approximate whole numbers, the pupil arrives at the idea that the atom must be made up of some fundamental building block of unit mass. The experimental evidence about the existence and comparative weights of the electron and proton is then introduced. Diagrams of the hydrogen atom, consisting of one proton and electron, and of the helium atom, consisting of four protons and electrons, can be drawn. Experimental evidence from the Rutherford nuclear study and the Moseley experiment is briefly described, and a second set of diagrams of the hydrogen and helium atoms drawn. The hydrogen atom consists of a nucleus of one proton and has one planetary electron. The helium atom has a nucleus of four protons and two electrons and two planetary electrons. The apparent discrepancy in the two diagrams of the helium atom should lead to pupil inquiry as to the cause of the difference.

This speculation might be directed by citing once more that Moseley's experiments indicated only two protons in the nucleus. Presentation of Chadwick's experiment in simplified form, in which mention is made of a new experimental particle that is not deflected by passage between positively and negatively charged plates, should lead to a simplified drawing of the helium nucleus. The drawing might first contain two protons and two particles composed of a proton and

electron, and the final diagram would show the new particle, represented by *n*, taking the place of the combined electron-proton particles.

The confusion resulting from the use of such terms as free proton, excess proton, and free and combined electron would then be eliminated. A statement to the effect that, experimentally, there are no electrons in the nucleus would clinch the matter. The terms atomic weight and atomic number now have a more significant difference. The use of the neutron also makes possible simpler diagrams of the nuclei of isotopes. The difference in nuclei is then seen to be due to difference in number of neutrons.

II. THE THEORY OF STRONG ELECTROLYTES (INTERIONIC ATTRACTION)

(*A*) *The Present State of Our Knowledge*

The Arrhenius theory of ionization was propounded long before the Bragg work on the ionic nature of crystals. Working on the assumption that conductance in solution depends on three factors—(1) the number of ions, (2) the speed of the ions, and (3) the valence of the ions—Arrhenius further assumed that the speed and valence of ions were constant and that changes in conductivity were due to changes in the number of ions. This was experimentally true for weak electrolytes, and by conductivity measurements it was possible to calculate the degree of ionization.

For strong electrolytes, however, grave discrepancies arose. In calculating the per cent ionization for strong electrolytes by the same method such results as the following appeared:

TABLE 2

1 *M* SOLUTIONS[1]

Univalent salts (KCl)	85 per cent ionization
Bi-univalent salts ($BaCl_2$)	73 per cent ionization
Tri-univalent salts ($AlCl_3$)	65 per cent ionization
Bi-bivalent salts ($CuSO_4$)	40 per cent ionization

These degrees of ionization were treated as actualities even though solutions of potassium chloride showed only properties of potassium and chloride ions, and no properties of molecules of potassium chloride. Arrhenius ascribed these differences in ionization to the formation of molecules.

The more recent interionic attraction theory, accepting the work of Bragg and others, assumes complete ionization. It ascribes changes in conductance with dilution to the electrical forces between charged ions. Each ion has about it an ionic atmosphere of oppositely charged ions which retard the speed of movement of ions through the solution. In other words, it assumes that the number of ions of strong electrolytes is always one hundred per cent and that valence is constant. Changes in conductivity, therefore, are due to changes in the speed of ions because of this ionic atmosphere. As a solution becomes more concentrated the attractive forces increase with a subsequent lowering of equivalent conductivity and apparent degree of ionization.

The experimental evidence favors the interionic attraction theory. Bragg's work shows that crystals of strong electrolytes are already completely ionized. All strong electrolytes of the same valence type show the same apparent degree of dissociation, and those of the higher valence type show a smaller apparent degree of dissociation on account of the greater strength of the ionic atmosphere. The formula, worked out by Debye and Hückel for the ionic strength of solution, according to the interionic attraction theory, takes into account the greater charges on the higher valence types and ascribes greater attractive forces to these higher charges. Experiment shows that the solubility product of difficultly soluble materials is increased by the presence of strong electrolytes and the higher valence type salts have a greater effect in increasing the solubility. Effects such as that of presence of potassium nitrate on solubility of calcium sulfate are well known.

Experiment also shows that the presence of the ionic atmosphere of a strong electrolyte will increase the ionization of a weak electrolyte. The following experiment worked stepwise will show this effect and can be useful in a high-school demonstration.

TABLE 3

DEMONSTRATION WITH ACETIC ACID (SALT EFFECT)

(1) Methyl Orange with water—orange-yellow
(2) Methyl Orange with dilute hydrochloric acid—red
(3) Methyl Orange with dilute acetic acid—almost as red as 2
(4) Methyl Orange with very dilute acetic acid—a very slight red-orange
(5) Same solution as (4), with much solid sodium chloride added—changes from red-orange to a very definite pink

This change in the ionization of very dilute acetic acid is due to the ionic atmosphere of sodium and chlorine ions which prevent the reformation of molecular acetic acid and consequent increase in pH and indicator effects. This experiment shows that there is such a thing as an ionic atmosphere and that it has significant and demonstrable results.

(*B*) *What Materials Shall We Present to High-school Pupils and Why?*

Most of this material does not lend itself to presentation on the high-school level. It is significant, however, to show that strong electrolytes are completely ionized in solution just as they are in the crystalline lattice structure and in the fused salts. It might also be important to show ionization as a continuous phenomenon in nature by demonstrating conductivity of salts in media other than water. An experiment, useful for demonstrating this phenomenon, is described later. This conductivity in other media has no significance in the interionic theory but is helpful in giving the pupil a complete picture of the phenomenon. This type of treatment will furnish the pupils with a truer conceptual basis for the college work on ionization.

Closely allied with the subject of ionization is the subject of valence and theories of valence. The textbook analysis, mentioned at the beginning of the article,

[1] CURTMAN, "Qualitative chemical analysis," 2nd ed., The Macmillan Co., New York City, 1938.

showed that in some instances ideas of valence were not presented in their true light and that consequently wrong ideas might result. One author shows an electronic picture of hydrochloric acid in which it looks like an electrovalent compound. Another author shows an electronic diagram of magnesium oxide which makes it look like a non-polar covalent compound. The difficulty is that we are too frequently satisfied with teaching the formation of a polar compound and its structure and with possibly a slight mention of non-polar compounds. It would probably be better to teach compound formation as due to (1) real electrovalence as shown in sodium chloride, (2) polar covalence as shown in hydrochloric acid and acetic acid, and (3) non-polar covalence as shown in carbon tetrachloride. This treatment also presents a more accurate picture and shows the gradation in types of valence that is responsible for variations in chemical behavior.

(*C*) *Method of Presentation to Pupils*

The groundwork for the correct approach to these concepts might consist of a review of the structure of such electrovalent compounds as sodium chloride with a redrawing of the electronic picture.

(*D*) *Demonstration* (*Conductivity of Fused Salts*)

A large crystal of potassium dichromate is placed between the electrodes in an electrode lamp hookup and the question asked, "If this crystal is made of ions why doesn't it conduct the current?" On heating the crystal in an evaporating dish with a Bunsen burner, fusion takes place very quickly, and the lamp lights. The pupils are asked to explain why the lamp lit after fusion. They should get the idea that heating provided additional energy which accounted for the motion of the ions and that the balanced electrostatic forces prevented such motion in the solid state. A brief report on Bragg's experiment would be helpful at this point. Potassium dichromate was selected because it fused very quickly. Other materials that also fuse easily are sodium hydroxide and silver nitrate. It would be ideal to use sodium chloride. This takes a little more time with an ordinary Bunsen burner, and only a small quantity may be fused. If a small porcelain crucible and a modern Tirrill burner are used, the fusion takes place within a reasonable time. With sodium chloride it is advisable not to use platinum electrodes. Sodium hydroxide also has an effect on platinum and, besides, may destroy the crucible. Iron or graphite electrodes work best with these materials.

The next question in the development should be, "How many ions are present in (*a*) the solid state, (*b*) the fused condition?" Then observation of the brightness of the lamp in the fused and dissolved condition (crystals in water) should lead to the idea that the material is practically all ionic in the solid, fused, and dissolved conditions.

(*E*) *Demonstration on Valence*

The three types of valence can be shown by using part of the above experiment to show that a fused salt (liquid) will conduct, while other liquids like acetic acid and carbon tetrachloride will not conduct. Addition of water to solid salt and to each of the above liquids will show that there are three different effects which can be explained on the basis of three different kinds of valence. The electrode lamp hookup is used in this experiment also. Originally, sulfuric acid was also tried as an example of a polar covalent compound which was much more ionized and therefore more polar than acetic acid. Ordinary laboratory sulfuric acid gave such a high conductivity even without the addition of water that it could not be used.

(*F*) *Demonstration on Ionization in Non-aqueous Media*

With a galvanometer, electrode (platinum), electric bulb hookup test the conductivity of (1) acetic acid (glacial acetic was allowed to solidify, remaining liquid poured off and sufficient acetic anhydride added to remove any water that might be present), (2) sodium chloride dissolved in this prepared acetic acid, and (3) sodium acetate in the acetic acid. The results were (1) no conductivity, (2) slight conductivity by galvanometer, but bulb does not light, and (3) greater conductivity by galvanometer, but bulb still unlit.

If solid potassium iodide is dissolved in acetone and the solution placed in the same setup, sufficient conductivity takes place to light the bulb. Iodine, as shown by the resultant brown coloration, is set free at he anode. Potassium is liberated at the cathode and a secondary action occurs in which bubbles of gas, probably hydrogen, are liberated due to the action of the liberated potassium on the enol form of the acetone. The resultant compound adheres to the electrode (cathode), and when the cathode is placed in a red litmus solution the litmus turns blue. That this litmus change was not due to the hydrolysis of any adhering potassium iodide was shown by placing a comparatively large quantity of the potassium iodide-acetone solution in red litmus with no effect. The potassium iodide is only slightly soluble, although much ionized. This experiment shows electrolysis in a non-aqueous medium and closely resembles the electrolysis of sodium chloride in water solution.

III. BRØNSTED-LOWRY THEORY OF ACIDS AND BASES

(*A*) *The Present State of Our Knowledge*

It is impossible in this brief treatment to present the many complicated phases of the theory and the information given here is more or less on an elementary level.

The classical concept of an acid is that of a substance which produces hydrogen ion in water solution. Experimental evidence now shows that (1) ionization takes place in many other media besides water; (2) indicator reactions, acidic action on carbonates, and catalytic activity by acids take place in other media besides water; and (3) (on a more complex level) indicator reactions, catalysis, action on carbonates, and measurement of hydrogen electrode potentials

take place and are measurable even in non-ionizing solvents like benzene.

Although item (3) (above) will not be considered at length in the discussion it is well established that the fundamental concept of an acid, according to Brønsted, amply covers and explains the experimental material. The Brønsted definition is, an acid is a substance that can dissociate into a proton and a corresponding base, *e. g.*,

$$\text{Acid} \rightarrow \text{proton} + \text{base}$$
$$HCl \rightarrow \text{proton } (H^+) + Cl^-$$
$$HAc \rightarrow \text{proton } (H^+) + Ac^-$$

This generalized definition is one of the most fundamental concepts in chemistry. Together with the other basic generalization

$$\text{Reductant} \rightarrow \text{oxidant} + \text{electron}$$

it serves to explain the two most fundamental chemical processes in terms of the two most fundamental units of matter, the electron and proton.

Another fundamental idea is that, in ionizable solvents, a double acid-base reaction occurs in which the solvent may serve as either an acid or a base depending on what is added. The typical reaction is

$$\text{Acid 1} + \text{base 2} \rightarrow \text{acid 2} + \text{base 1}$$
$$HCl + H_2O \rightarrow H_3O^+ + Cl^-$$
$$HCl + NH_3 \rightarrow NH_4^+ + Cl^-$$
$$HCl + HAc \rightarrow H{\cdot}HAc^+ + Cl^-$$
$$H_2O + NH_3 \rightarrow NH_4^+ + OH^-$$

Examples are (1) HCl in water; (2) HCl in liquid ammonia; (3) HCl in acetic acid; (4) NH_3 in water.

In line with the more fundamental concept that acid yields proton plus base, it is evident that acid 1 has a conjugate base 1, just as base 2 has a conjugate acid called acid 2. Examples 1 and 4 show the solvent acting as either an acid or a base. A further conclusion is that hydrogen ions in water solution are really hydrated protons, H_3O^+, called the hydronium or oxonium ion. This ion is similar to the solvated proton in ammonia, NH_4^+, and the solvated proton in acetic acid, $H{\cdot}HAc^+$. A comparatively new idea is that the negative ion, Cl^-, is now a base just as OH^- is the ordinary base in the present water system. Substances like sodium hydroxide and potassium hydroxide, which are commonly called bases, are salts and not bases in this newer concept. They may be treated as bases, however, because they furnish a large supply of the strongest base or proton acceptor in aqueous solution, the OH^- ion.

A salt is now simply defined as an ionic compound and its definition need no longer be tied up with neutralization.

In ionizable media neutralization now becomes a generalized definition in which a base and an acid unite to form molecules of solvent.

$$\text{In water} \quad H_3O^+ + OH^- \longrightarrow 2H_2O$$
$$\text{In ammonia} \quad NH_4^+ + NH_2^- \longrightarrow 2NH_3$$

Hydrolysis need no longer be considered a separate phenomenon in water because there is an easy explanation. Sodium acetate reacts basically because it yields the acetate ion which is a base. Ammonium chloride reacts acidically because it yields the ammonium ion which is an acid. This presents a simpler explanation in many cases, but in all cases it is still necessary to realize that water is an ampholyte, a substance capable of associating or dissociating a proton.

Strength of acids depends on such factors as the dielectric constant of the solvent and the ability of the solvent to accept protons. Acids show marked differences in strength in other solvents when compared with their strength in water. Experiments in non-ionizable media like benzene show particularly significant results in the acid strength of so-called strong acids in water.

(*B*) *What Material Shall We Present to High-school Pupils and Why?*

The idea is that, because of such similar phenomenon as conductivity and indicator reactions in other ionizable solvents besides water, we can extend the definition of an acid to a more fundamental concept—an acid is a substance that can donate a proton and a base can accept the proton. This gives a more nearly true picture of one of the most fundamental concepts. We teach the oxidation-reduction concept in terms of the electron, why not teach this other fundamental concept in terms of the proton?

Practically all of the other ideas must be rejected. The concept is in a state of flux so that even in modern college texts the ideas are not too clearly presented. Any further attempt to extend the ideas would lead to confusion in the minds of the pupils that would destroy any conceptual basis for college teaching. There is little material that can be demonstrated to the pupil on a simple basis.

The indicator reactions that would be demonstrated to the pupils would naturally cause an extension of the idea of neutralization as discussed above, although this need not be emphasized.

(*C*) *Method of Presentation to Pupils*

In our presentation of the ionic theory the pupils arrive at the definition of an acid as a subtance that furnishes hydrogen ion in water solution. A base is defined as a substance that furnishes hydroxyl ions in water solution. The demonstration showing ionization in acetic acid and acetone could be used at this point to bring out the idea of ionization in other media. The definition is then extended to emphasize the acid as a proton donor. Comparison of the behavior of the hydrated proton in water with the ordinary properties of the electrical particle would lead to the idea that there is a difference in these two particles and that an acid has a hydrated proton. The term oxonium or hydronium ion might be introduced as well as the symbol, ϕ H_3O^+. The simple ionic equation, now used for neutralization, might be used to bring out the idea of

the base as a proton acceptor. The new equation using the oxonium ion would then cause a somewhat enlarged view of neutralization as resulting in the formation of solvent.

$$H^+ + OH^- \rightarrow H_2O$$
$$H_3O^+ + OH^- \rightarrow 2H_2O$$

These might serve as the main outgrowths of one of the experiments described which show indicator effects and neutralization in media other than water.

(*D*) *Demonstrations on Indicator Reactions and Neutralization*

(1) A one per cent solution of basic fuchsin in (*a*) water and (*b*) refined glacial acetic acid is the indicator used, respectively, in (*a*) water and (*b*) refined acetic acid media. Solid oxalic acid is used as the acid and solid sodium acetate as the base. Incidentally, the fact that NaAc acts as a base with litmus in water and acts as a base in HAc should prove stimulating to pupil inquiry.

TABLE 4

Basic Fuchsin in Water		*Same Indicator in Acetic Acid*	
Reagent	*Resultant color*	*Reagent*	*Resultant color*
(*a*) Oxalic acid in water	Purple	(*a*) Oxalic acid in acetic acid	Purple
(*b*) Sodium acetate in water	Pink	(*b*) Sodium acetate in acetic acid	Pink
(*c*) Addition of excess solid NaAc to purple solution (*a*), from which the excess solid acid is removed causes the purple color to disappear and the pink color appears.		(*c*) Duplication in water of this procedure causes the same results. Changes in both media seem to indicate neutralization.	

(2) The same experiment will also work with methyl orange indicator in methyl alcohol. One or two drops of this indicator are added to either the water or methyl alcohol medium. The same acid and base may be used.

TABLE 5

Methyl Orange in Water		*Same Indicator in Methyl Alcohol*	
Reagent	*Result*	*Reagent*	*Result*
(*a*) Oxalic acid in water	Red	(*a*) Oxalic acid in methyl alcohol	Red
(*b*) Sodium acetate in water	Yellow	(*b*) Sodium acetate in methyl alcohol	Yellow
(*c*) Add excess oxalic acid as in Experiment 1 and the yellow disappears and red results. The reverse procedure does not give as good results near yellow as expected.		(*c*) Duplicate (*c*)—similar results. The reverse in which excess sodium acetate is added to the acid gives orange.	

(3) If these materials are not available the common indicator, phenolphthalein, will give good results with oxalic acid and solid sodium hydroxide used in water and methyl alcohol solvents.

The experiment with basic fuchsin is probably most legitimate and the last one employing phenolphthalein probably the least legitimate. However, the pupils are already familiar with sodium hydroxide and probably with oxalic acid. Since saturated solutions are being dealt with in all cases, we do not get as marked effects as might be possible with dilute solutions.

ONE HUNDRED HIGH-SCHOOL CHEMISTRY PROJECTS

J. O. DERRICK

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EARLY in my teaching career I realized that in order to hold the interest of my group, I must supplement the text and required laboratory work with materials that appeal to a variety of interests. With that in mind I began making a list of references covering projects that students could do at home, or in the laboratory after school. Over a period of ten years some of these references have been extremely valuable to me, and I am submitting them with the hope that they may be of value to other teachers, especially those who have not taught long enough to accumulate teaching aids and information suitable for club programs.

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CR_2O_3 AS A CATALYST IN $KCLO_3$ DECOMPOSITION

MARTIN MEYER

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OF ALL the substances which catalyze the thermal decomposition of $KClO_3$, Cr_2O_3 seems, from the standpoint of low temperature and speed of reaction, to be the most efficient. As little as one per cent by weight will work satisfactorily and it is useless to employ more than five per cent.

The catalytic cycle seems to involve $K_2Cr_2O_7$, which functions equally well as a catalyst. Some chlorine is evolved, but as it is removed in collecting over water, this is no disadvantage.

The familiar student experiment of preparation of oxygen is better done by the following modifications of the usual directions: To five grams of $KClO_3$ add one crystal of $K_2Cr_2O_7$ about the size of the head of a large pin. Heat gently with the usual setup.

The method has these advantages: it proceeds smoothly at a relatively low temperature and may be stopped at any time by cooling; when all oxygen is evolved the contents of the tube obviously solidify; more $KClO_3$ may be added if desired without more catalyst; the test tube is easily washed out with hot water.

FROM THE PRESIDENT OF THE UNITED STATES:

(*The following letter has been made public by the Federal Security Agency, and we think it important enough to print in full.*)

My dear Mr. Administrator:

Reports have reached me that some young people who had planned to enter college this fall, as well as a number of those who attended college last year, are intending to interrupt their education at this time because they feel that it is more patriotic to work in a shipyard, or to enlist in the Army or Navy, than it is to attend college. Such a decision would be unfortunate.

We must have well-educated and intelligent citizens who have sound judgment in dealing with the difficult problems of today. We must also have scientists, engineers, economists, and other people with specialized knowledge, to plan and to build for national defense as well as for social and economic progress. Young people should be advised that it is their patriotic duty to continue the normal course of their education, unless and until they are called, so that they will be well prepared for greatest usefulness to their country. They will be promptly notified if they are needed for other patriotic services.

Sincerely yours,
FRANKLIN D. ROOSEVELT

THE WHITE HOUSE
WASHINGTON

A SIMPLE EXPERIMENT ILLUSTRATING DIFFUSION

JOHN H. GARDNER

Washington University, Saint Louis, Missouri

AS A means of rendering diffusion visible to a class of students, a test tube containing solutions of colored salts in a succession of layers has frequently been used. The execution of this experiment requires considerable care and the tube, when prepared, must be carefully protected from agitation if the experiment is to be a success. If gels are used instead of solutions, very much less manipulative skill is required and the finished tube is not affected by agitation in handling. A simple form of such an experiment has been devised.

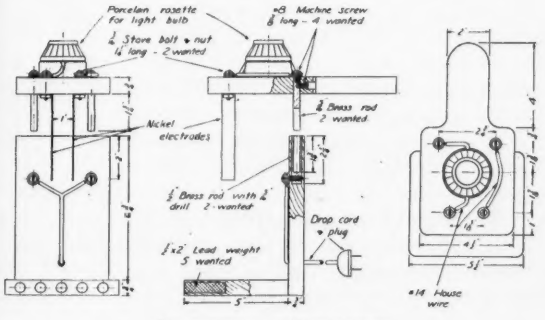
A test tube is filled to a depth of about five centimeters with a clear gelatin solution which is allowed to set to a rigid gel. About an equal amount of the gelatin solution colored intensely red by the addition of a small crystal of fuchsine is then poured into the tube and allowed to set. The colored gel is then covered with a layer of paraffin to prevent putrefaction. In about an hour a noticeable diffusion of the fuchsine into the colorless layer will have taken place, the penetration continuing at a diminishing rate for several days. At all times, the original line between the colored and colorless layers remains visible.

« « OUT OF THE EDITOR'S BASKET » »

THERE have been many methods suggested for the grading of quantitative analytical experiments. One which has been sent in by W. H. Walker, of Morris Harvey College, seems commendable. The formula, $Grade = (A - X)(B - Y)F$, is used, in which X is the maximum percentage deviation of the results turned in, or the *precision;* and Y is the percentage difference between the average of the results turned in and the correct value, or the *accuracy*. A and B are empirical constants, which depend upon the maximum values of X and Y which are permitted, and $F = 100/AB$. In using this grading method the instructor first sets a standard of accuracy and precision, that is, decides upon maximum values for X and Y which he will accept (say, 0.4 per cent for each). He then picks out the corresponding values for A and B from the table below (3.0 for each, in this case), and calculates the grade for any given set of results from the formula. The following table is based upon a passing mark of 75 per cent, but may be modified for any other passing grade.

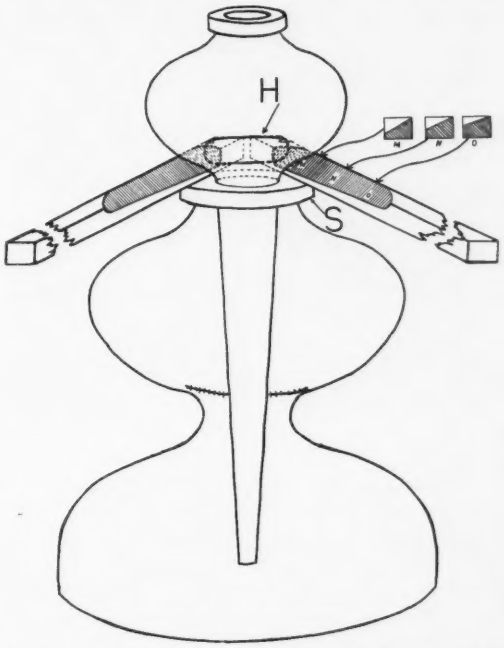
X or Y:	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
A or B:	0.8	1.5	2.2	3.0	3.7	4.4	5.1	5.9	6.8	7.8

• P. R. Fehlandt, of the College of Puget Sound, is one of our most faithful "gadgeteers," and three of his contributions are before us. The first is the proposal to use an ordinary one-gallon gasoline can as an unbreakable steam-generator. The spout, with a rubber connection, serves as an outlet. A short piece of copper tubing is soldered into the top of the can, and a length of glass tubing inserted through this, with a rubber sleeve, is a satisfactory pressure and safety device. There will be many to whom this idea is not new, although they may have used a glass tube through a cork in the mouth of the can.


Porcelain rosette for light bulb
#8 Machine screw 1/8 long - 4 wanted
1/4 Stove bolt & nut 1/4 long - 2 wanted
1/4 Brass rod 2 wanted
Nickel electrodes
1/4 Brass rod with 1/4 drill 2 wanted
Drop cord & plug
1/4 x 2 Lead weight 5 wanted
#14 House wire

CONDUCTIVITY APPARATUS

Everyone seems to have his own idea of a suitable apparatus for the demonstration of conductivity, and here is another one. As usual, a lamp is in series with electrodes dipped into the solution. There is always difficulty in cleaning the electrodes between times, and in the form of apparatus shown in the accompanying illustration this is minimized by the use of plug and socket joints, so that the whole upper part, with electrodes and lamp, can be detached for washing. Holes are bored in the base and filled with lead, for stability.



DEVICE FOR LOOSENING "FROZEN" KIPP GENERATORS

A device for loosening "frozen" Kipp generators is shown in the accompanying illustration. It is essentially a large wooden nutcracker with the jaws cut wedge-shaped, so that when placed on the shoulder, S, of the generator and the jaws squeezed together, the inner member of the generator is lifted out of the frozen joint. The jaws, of $2'' \times 2''$ material, should be about six feet long, for mechanical advantage, and cut with a variable wedge-slope, to fit different shaped generators. A loop of heavy wire, H, hung in deep notches, will make a satisfactory hinge.

• An ingenious method for maintaining a regulated gas flame has been proposed by Philip S. Chen, of Atlantic Union College, and is shown in the accompanying illustration. A large needle is hung on a thread from the end of the valve handle of the gas cock. When the gas has been adjusted to the desired height a small ink spot on a sheet of paper is firmly placed directly

under the needle point. The gas may then be turned off when necessary, with some assurance that the valve can be adjusted to the same opening again. We hope your gas pressure is constant!

• Another example of the well-known contrast between one man's poison and another man's meat is the observation that war, with its attendant disruptions of trade and its restriction of the supplies of raw materials, has set chemists feverishly to work seeking reasonably priced substitutes for such things as varnish gums, rare metals, glasses and fibers.

The Merck Review reminds us that: although "replacement of crude drugs and medicinals is difficult, and though synthetic counterparts have been found for ephedrine, camphor, menthol, and thymol, substitutes are still urgently needed for quinine and many of the minor alkaloids."

Philatelic fans among our readers will be interested in an article in the July number of *The Merck Review*, "Physicians and Chemists on Postage Stamps," by Frederick A. Weiss. A splendid page of reproductions shows 43 stamps from various countries, mostly adorned with the portraits of medicos, to be sure. Seven or eight bona fide chemists can be recognized, however.

• The American Association of Junior Colleges reports that out of 426 junior colleges 293 offer terminal curricula. That means, presumably, that the latter number turn out students who are supposedly trained to do something in particular. Closer investigation of the various fields covered shows eight giving training in chemical engineering, six in "laboratory technique," five in oil technology. These are the only ones listed which have any apparent chemical significance, and while the numbers are not large perhaps even this many will be something for the A. C. S. Committee on Professional Training to worry about in its spare time—if any.

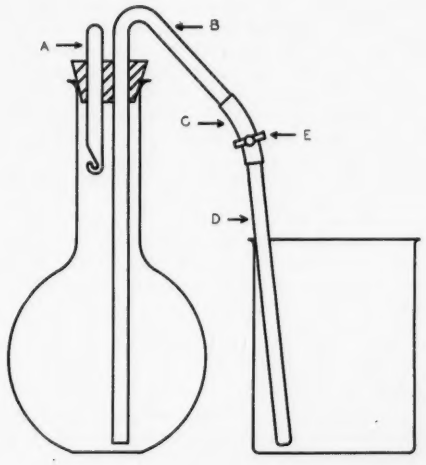
• From Chicago comes the announcement that the Armour Institute of Technology and the Lewis Institute, each with nearly fifty years of honorable record, have entered into an agreement to form the ILLINOIS INSTITUTE OF TECHNOLOGY. The backgrounds and reputations of the two component colleges are to be recognized in the new institution by use of the names ARMOUR COLLEGE OF ENGINEERING of ILLINOIS INSTITUTE OF TECHNOLOGY, for the Division of Engineering, and LEWIS INSTITUTE OF ARTS AND SCIENCES of ILLINOIS INSTITUTE OF TECHNOLOGY, for the Division of Arts and Sciences. The third division of the new institute will be the ARMOUR RESEARCH FOUNDATION, which has been in existence since September, 1936. The Research Foundation will continue to render a professional research and experimental engineering service to industry.

The union, according to statistics available, results in the formation of a center of technological education having about 7000 students in the day and evening classes, making ILLINOIS INSTITUTE OF TECHNOLOGY one of the largest schools of its kind in the nation. Henry T. Heald is to be its first president.

• Donald Hunter and L. S. Guss, of South Dakota State College, propose the following method for introducing samples into the conventional Victor Meyer apparatus, illustrated by a sketch: A small bulb is blown from 6-mm. tubing and drawn into a capillary. The sample is introduced into this and the capillary sealed. A long glass rod is inserted in a one-hole rubber stopper, to fit the top of the Victor Meyer tube. The end of the rod is melted and the capillary of the sample bulb forced into it. When fixed in the top of the apparatus, as shown in the sketch, a little lateral pressure will break the capillary, and the bulb and sample drop to the bottom of the tube. If the student realizes the fragile nature of the seal, he will appreciate the care necessary in the operation.

• This month we must mention *The Boston College Crystal*, a little periodical issued by the Boston College Chemists' Club. It is entirely managed and written

by students and the last number we have contains several very interesting articles. One department is devoted to abstracts of the papers recently given in the graduate seminar. Such reporting can well be a valuable element in a student's training. Incidentally, it contains an account of the occasion on which the Northeastern Section of the American Chemical Society played host to the officers of student chemistry and chemical engineering clubs at the monthly dinner and meeting.

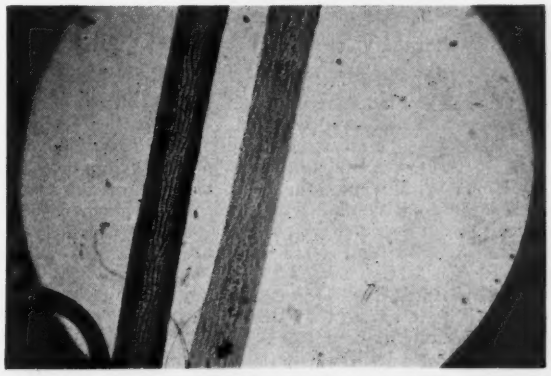


● R. W. Fessenden and N. P. Stevens, of Massachusetts State College, send in an illustration and description of apparatus to determine the equivalent weight of a metal. It closely resembles that which has long been in use for the determination of the density of oxygen. About 400 ml. of dilute HCl are put in the flask and the delivery tube, *B*, *C*, *D*, filled and manipulated to free it of all air bubbles. (If you can't discover how to do this, better just skip the experiment.) The pinchclamp, *E*, is then closed. The weighed sample of the metal, wrapped securely in copper wire, is hung on the glass hook, *A*, and the stopper inserted. A little water is put in the beaker, the pinchclamp opened, the two water levels equalized, and the clamp closed again. A dry beaker is substituted and the clamp opened. If no liquid siphons over the apparatus is airtight. The metal is shaken off the hook and allowed to dissolve, while the hydrogen forces liquid over into the beaker. When the reaction is complete, the levels are equalized, the clamp closed, and the volume of liquid measured. This is equivalent to the volume of hydrogen produced, and from it, with the pressure, temperature, and vapor pressure (assumed the same as that of water), the equivalent weight can be calculated. The authors recommend the following approximate weights of metal: Al, 120 mg.; Zn, 610 mg.; Mg, 250 mg. The acid should be about $2^1/_4 M$ in the first two cases and $M/3$ in the latter. The reaction time will be one-half to one and one-half hours.

● S. B. Arenson has written to tell us of something that the University of Cincinnati has been doing for the last six years. This is a series of orientation lectures on "The Application of the Physical Sciences," given annually to the 1000 highest ranking junior and senior high-school students interested in science. A list of interesting topics has been covered, too long to be given here in detail. Two series of lectures alternate annually, so that a given student may, if he is eligible, have the opportunity to hear all 14 or 16 of the lectures during his last two years in high school.

The teachers of physical science in all the local secondary schools were asked to send in the names of the students in the upper ten per cent of their classes and a ticket was sent to each of these, for admission to each lecture of the series. This brought an eighty per cent attendance of those invited. A request to admit teachers at the same time was at first refused, but when the attendance later became very large it was not thought objectionable to admit a few adults.

The venture is reported to be very successful. Students get a preview of university lectures and laboratories and are encouraged by the realization that their intelligence is respected and rewarded. The University profits from the increased contact with its public and, particularly, with the secondary schools.



MICROPHOTOGRAPH OF HAIRS OF WHITE RABBIT (LEFT) AND MUSKRAT (RIGHT)

● Occasionally one wants to take a microphotograph but is discouraged because he has no elaborate equipment. Mr. I. A. Goldstein, of Brooklyn, tells how it can be done with an ordinary camera, using roll film. His camera was a Junior Kodak with an *f*. 6.3 lens. Adjust the condenser of the microscope according to the density of the object. Open the lens of the camera wide and focus at infinity. Remove the lens from a portrait attachment and place the tube tightly over the ocular. Focus the object, then use a ground glass to center it. Place the camera so that the lens fits into the portrait-attachment tube. Exposure time will be four to ten seconds, with Verichrome film. A blue or green filter had best be used. The picture above shows what can be done with such simple equipment.

« « « WHAT'S BEEN GOING ON » » »

"HELVETIUM" AND "MOLDAVIUM," ELEMENTS 85 AND 87?

ANNOUNCEMENTS of the "discovery" of the elements of atomic numbers 85 and 87 have appeared from time to time during the past fifteen years, but until recently none has been confirmed.[1] At present, the evidence for the occurrence in nature of both elements 85 and 87 is very convincing, and the chemistry of element 85 has been investigated by means of a radioactive isotope, produced artificially.

ELEMENT 85

Corson, Mackenzie, and Segrè, of the University of California, announced at the Washington Meeting of the American Physical Society, April, 1940, that the artificially radioactive element 85 is produced by bombarding bismuth with 32-Mev. alpha particles.[2] The behavior of the product is complex: by the emission of alpha particles, forty per cent of it reverts to bismuth, but due to the emission of neutrons in the original impact the isotopic species produced differs from that of the target, in that it probably has a mass number of 207 and is radioactive. By the capture of a K-shell electron, sixty per cent of it is transmuted into AcC′, a known isotope of polonium. These nuclear reactions may be summarized as follows:

$$ {}_{83}\mathrm{Bi}^{209} + {}_{2}\mathrm{He}^{4} \rightarrow {}^{*}[85]^{211} + 2n $$

$$ \begin{aligned} 40\% - {}^{*}[85]^{211} &\xrightarrow{7.5\ hours} {}^{*}{}_{83}\mathrm{Bi}^{207} + {}_{2}\mathrm{He}^{4} \\ 60\% - {}^{*}[85]^{211} + e^{-} &\rightarrow {}^{*}{}_{84}\mathrm{AcC}'^{211} \end{aligned} $$

Because of the radioactivity of the isotope of element 85, it has been possible to trace through some of its chemical reactions. It appears to be more markedly electropositive than the other halogens; it is precipitated, for example, by hydrogen sulfide from a solution 6*N* in hydrochloric acid, but is not precipitated by silver nitrate from its solution in nitric acid, when iodide is used as a carrier. It does, however, appear to be quite volatile, since the bombarded bismuth loses its activity below 275°C. It has also been reported that element 85 is concentrated in the thyroid.

In an Associated Press release, dated July 24, it was announced from Bern, Switzerland, that Dr. Walter Minder, chief of the Radium Institute of Bern, has isolated element 85 and named it "helvetium."[3] His claim to its discovery may, however, be disputed by Hulubei and Chauchois, who reported in July, 1939, that they had detected X-ray spectral lines, on excitation of the disintegration products of radon, which could be associated only with element 85[4]. Though predominantly an alpha-ray emitter, radon possibly emits beta rays also, and is thus transmuted to element 85. Until Minder's data are published, judgment as to the priority of the claims must be reserved.

ELEMENT 87

In 1914, St. Meyer, Hess, and Paneth[4] reported that although actinium normally emits beta rays, it is also feebly alpha-ray active, emitting particles of 3.5 cm. air penetration. For several years this activity was explained as being due to the presence of traces of protactinium. On January 9, 1939,[5] Mlle. Marguerite Perey confirmed the earlier explanation and announced that the product of the disintegration, AcK, was a natural radioactive isotope of element 87. Using lanthanum as the carrier for the actinium, the latter was freed of all its known radioactive neighbors and showed negligible activity. During the two hours following the purification, the beta-ray activity rose abnormally and this behavior was explained by the presence of a new element, AcK, with a half-life period of 21 minutes. Using cesium as a carrier, the chemical properties of AcK were investigated and found to be those of an alkali metal; thus, it is not precipitated by hydrogen sulfide, but is carried down as the perchlorate. It is readily separated from second, third, and fourth group elements, being dissimilar to barium, cerium, and lead.

On June 8, 1936,[6] Horia Hulubei announced that by a very sensitive X-ray spectroscopic method, he has demonstrated the presence of element 87 in the alkali metal salt concentrate extracted from pollucite. Since his original work, he has taken great precautions to eliminate the possibility of false identification of the spectral lines and has repeatedly confirmed his findings, using different samples, various spectrographs equipped with crystals of either quartz or mica, and by working in several spectral orders. Furthermore, he believes he has shown that element 87 is concentrated in the mixture of alkali metals by the lower solubility of its chloride in alcohol. Of the minerals, beryl, lepidolite, pitchblende, pollucite, soddite, and Bavarian autunite-colombite, the first two gave negative results and the last the greatest prospects for its isolation.

Hulubei claims the discovery of element 87 and has proposed the name "moldavium" (Ml) in these words:[7] "Pour cet élément 87, j'ai proposé le nom de *moldavium* (Ml) en homage à la Moldavie, province roumaine, marche avancée vers l'Est de la latinité."

If the results of the investigations of both Mlle. Perey and Hulubei are verified, at least two isotopes of element 87 must occur naturally, one with a long life and the other with a transitory existence.

—LAURENCE S. FOSTER

FROM the Arthur D. Little laboratory comes the announcement that electrolytic polishing is now taking its place with surface coatings and mechanical methods for producing smooth, lustrous metal surfaces. Essentially the opposite of electroplating, the new method depends upon metal removal. Metals are immersed in a bath, usually acidic, and electric current opposite in direction to that for electroplating is applied. The surface starts to dissolve and, under proper conditions, a dull and non-reflecting surface becomes much more lustrous and mirror-like, as if mechanically buffed or burnished. In some instances, particularly with stainless steel, this anodic luster finish surpasses in depth of tone and brilliancy that obtained by mechanical polishing. The treated surface is claimed to be an excellent base for subsequent electroplating and even to give improved resistance to corrosion.

Theories explaining the action differ, but all agree that the net result is a preferential attack on the high protruding parts of the metal surface, which results in leveling and smoothing. One plausible theory suggests the formation of a film over the metal surface which covers and protects the low parts but exposes the

[1] The names "alabamine" and "virginium" have not been generally accepted and the "magneto-optic effect" of Professor Allison of Alabama Polytechnic Institute is at present not considered to have any physical significance, *cf.* COMSTOCK, *Phys. Rev.*, **51**, 776 (1937).

[2] CORSON, MACKENZIE, AND SEGRÈ, *ibid.*, **57**, 1087 (June 1, 1940).

[3] *Cf.* also TURNER, *Phys. Rev.*, **58**, 181 (July 15, 1940).

[4] *Wiener Ber.*, **123**, 1459 (1914).

[5] PEREY, *Compt. rend.*, **208**, 97 (1939); *J. Phys. Radium*, **10**, 435 (1939).

[6] HULUBEI, *Compt. rend.*, **202**, 1927 (1936); *cf. ibid.*, **205**, 854 (1937); **209**, 675 (1939).

[7] *Compt. rend.*, **209**, 678 (1939).

high points to attack. This protecting film is believed by some to be a poorly conductive viscous layer of soluble metal salts formed when the metal dissolves; others suggest that the film may be composed of metal oxide, of gas, or of insoluble reaction products. Whatever the theoretical explanation, at least four companies are using electrolytic polishing methods for finishing stainless steel, and others are considering the method for parts of their products.

A NOVEL type of compound recently introduced is a wax, completely soluble in water, forming a clear, transparent solution. It dissolves readily in benzene and toluene, acetates and acetone, but is not appreciably soluble in petroleum products, nor in turpentine, waxes, or fats. It has a greasy feel, suggesting lubricating action for uses where actual greases are impractical.

DR. A. E. ALEXANDER, until recently holder of the Pearl Fellowship at Mellon Institute, has been working on pearls, seeking to gather complete scientific data on all gems originating in pearl-bearing molluscs.

Some of the results of this research revealed that not all pearls are composed of the orthorhombic variety of calcium carbonate, aragonite. Several large natural pearls, on sectioning, have been found to be, in part, of the much commoner hexagonal form of calcium carbonate, calcite. In another part of the work, it was learned that the Japanese cultured pearl possesses a large mother-of-pearl core, which, in representative specimens, averages from 75 to 90 per cent of the total linear diameter. This finding is at variance with implications in published statements generally accepted by the buying public as valid. Another phase of the research program involved testing equipment in use to distinguish cultured pearls from natural pearls, to lay down methods whereby this equipment could be improved. For quick, accurate determination, a good many pearls can be examined at one time. The X-ray fluorescence of cultured and fresh-water pearls has been shown to lie in the chemical composition. Where internal structural information is desired, the use of soft X-rays may be effectively employed. By this method, an entire pearl necklace can be radiographed in less than one minute, the resulting negative registering in a clear-cut manner the internal structural differences that distinguish natural pearls from those that have been cultured.

ADOLF WINDAUS

(Frontispiece)

ADOLF WINDAUS, born in Berlin December 25, 1876, decided to become a chemist after completing four semesters of medicine. Under Kiliani's sponsorship he prepared a dissertation on digitalis and received the doctorate at Freiburg in 1899. He continued his training by acting as voluntary assistant to Emil Fischer at Berlin, and then returned (1901) to Freiburg to begin his independent career as teacher and investigator. In 1913 his demonstrated ability brought him a call to succeed Pregl at Innsbruck; in 1915 he was invited to occupy the corresponding chair of applied medical chemistry at Vienna, but he chose rather to succeed Wallach as director of the chemical institute at Göttingen, where he has remained despite numerous attractive offers, both academic and industrial.

At Kiliani's suggestion, the young medico-chemist, in 1901, attacked the elucidation of the constitution of cholesterol, a fateful choice. The series of studies issued by him and his co-workers extended over thirty years before the difficult problem received its final solution, but equally important was the light these researches shed on the analysis of the structures of sterols, bile acids, heart poisons, saponins, sex hormones, the antirachitic vitamin.

The formation of methyl imidazole from dextrose, the constitution of histidine, the synthesis of histamine, the studies of colchicine, are patently of great importance to physiological chemistry. The discovery that digitonin and cholesterol form a slightly soluble molecular compound in which digitonin has lost its hemolytic action gave a simple explanation of the observation that cholesterol detoxicates saponins. The complicated stereochemical relationship of the sterols and the bile acids was greatly clarified by his investigations.

In 1925 Windaus began his now famous investigations of the antirachitic vitamin. The observations of American and English workers had made it probable that vitamin D was related to the sterols, and Hess asked Windaus to participate in this study. Hess had found that cholesterol, even after fifteen recrystallizations, was rendered active antirachitically by irradiation with ultra-violet light. Windaus' suspicion that a small quantity of an isomer of higher energy content had been produced proved false because pure cholesterol could not be activated. He came to think that the provitamin might be a poly-unsaturated sterol, present as an impurity in the cholesterol. Tests of all the known sterols showed that ergosterol, a sterol with three double bonds, isolated from yeast a few years previously by Windaus, had all the properties of the provitamin, and, in fact, it becomes active on irradiation. The isolation of this photochemical product in crystalline form required four years of tenacious labor, because a series of six reaction products are formed when ergosterol is irradiated. After the constitution of cholesterol was established, Windaus determined the structure of ergosterol and was thus able to elucidate the formation of vitamin D.

It was found that natural and synthetic vitamin D showed differences in animal experiments. Ergosterol and cholesterol differ with respect to the system of two conjugated double bonds in ergosterol. Windaus introduced a second double bond into cholesterol and the resulting dehydrocholesterol on irradiation gave an active product identical with natural vitamin D, whose isolation was accomplished shortly thereafter in the Göttingen laboratory. Also vegetable sterols are converted into provitamins by the introduction of a new double bond, showing that there is a whole series of antirachitic provitamins and vitamins.

Windaus clarified the structure of the plant sterols, stigmasterol and sitosterol. His excellent studies of the preparation in pure form and the structure of vegetable heart poisons and neutral saponins have recently been brought to a successful conclusion by Tschesche at Göttingen. These materials have been found to be closely related structurally to the sterols. The same is true of the sex hormones, whose study, also at Göttingen, by Butenand, was made markedly easier by the work of Windaus on cholesterol, etc.

In 1929, the study of the antiberiberi vitamin was taken up in Göttingen. The first success was the isolation of crystalline vitamin B_1 from yeast. It had previously been isolated from rice polishings by Jansen. The empirical formula of the hydrochloride was proved to be $C_{12}H_{18}O_2N_4SCl_2$. Oxidative and hydrolytic scissions gave a series of crystalline fragments, whose constitution was clarified by Williams (New York) and Windaus. The artificial synthesis of this physiologically important food accessory is thus probably assured.

Many honors have come to Adolf Windaus. In 1928 he became the twelfth German chemist to receive the Nobel prize.—*Contributed by Ralph E. Oesper, University of Cincinnati*

« « « « RECENT BOOKS » » » » »

GENERAL CHEMISTRY. A FIRST COURSE. *Leona E. Young*, Associate Professor of Chemistry, Mills College, and *C. W. Porter*, Professor of Chemistry, University of California. Prentice-Hall, Inc., New York City, 1940. xi + 644 pp. 186 figs. 15 × 23 cm. $3.50.

The authors state in the preface: "In many colleges and universities a first course in chemistry, for which high-school chemistry is not a prerequisite, is included in a 'Letters and Science' curriculum. This outline represents an attempt to provide a textbook for such a course. The scope of the text is broad enough and the topics treated in sufficient detail to justify college credit." In style, vocabulary, and material covered, this "First Course" is nearer to the high-school texts than to the currently used first-year college texts. It is non-mathematical and essentially descriptive in character. Its applications appear to be oriented toward the interests of the "consumer." In the simplified, restricted treatment there is no indication of the current controversies on the theory and teaching of chemistry. There is practically no background or reference material; the student could learn or memorize all the material in the book.

The book teaches without any qualification that there is a molecule of salt with the formula NaCl. Except for the formulas in the brief organic chapters, and the diagrams for electronic configurations of the mercurous ion, Hg_2^{++}, and a few simple "molecules" such as H_2O, NaCl, MgF_2, and H_2S, one finds only empirical formulas, used without explanation in terms of atomic, molecular, or crystal structure. The only statement bearing on the crystal lattice which the reviewer found is the short sentence on page 309 stating that "in crystals the atoms are arranged in a regular way...." Elsewhere only macrocrystals are called crystalline; anhydrous salts such as Na_2CO_3 are called "non-crystalline." The electromotive series of the metals is not mentioned until page 485. The law of mass action and the related solubility product and ion product constants are not mentioned at all. One result is that the student will not learn (page 253) that alkaline solutions have a pH value. The traditional definitions of acids, bases, and amphoteric substances are taught without mention of Brønsted's generalizations. The student will read the unqualified statement that a solution of NaCl has twice the boiling point elevation of an equivalent sugar solution without wondering why Arrhenius and others thought that ionization of salts is not complete.

All numerical problems are kept on a simple level, atomic weights being reported as whole numbers, with sometimes unfortunate results.

In the reviewer's experience, students come to college from high-school chemistry courses with a number of misconceptions. The students using this book will acquire the following ones: (page 17) that some chemical symbols were derived from the Latin names "to avoid confusion," *e. g.*, that iron was not given the symbol I to distinguish it from iodine; (page 17) that coal is a form of carbon; (page 39) that a saturated solution contains all it can hold (leading to an absurd definition for the supersaturated solution); (page 51) that a catalyst does not enter into a chemical reaction; and (page 52) that "sea level" enters into the definition of the standard atmosphere.

The book is remarkably free from typographical and clerical errors. It is interesting and well written. In view of the difficulties inherent in a simplified discussion of phenomena which are not always simple, one must compliment the authors for their general accuracy and clarity. The chief weaknesses of the book are its traditional character in a day of great scientific change and its assumption that a college student who has not had a high-school chemistry course should take a course of the high-school type in college.

High-school teachers in the better high schools who prefer a text of the traditional type will find this an interesting and well-written book suitable for adoption in their classes. Teachers who find the current first-year college texts too difficult for their classes will also welcome this new book; those who find the current texts generally satisfactory will not find it an adequate text or reference book.

LUKE E. STEINER

OBERLIN COLLEGE
OBERLIN, OHIO

LABORATORY MANUAL FOR GENERAL CHEMISTRY. A FIRST COURSE. *Leona E. Young*, Associate Professor of Chemistry, Mills College, and *C. W. Porter*, Professor of Chemistry, University of California. Prentice-Hall, Inc., New York City, 1940. iv + 255 pp. 41 figs. 19 × 25.4 cm. $1.95.

The laboratory manual, designed to accompany the textbook of these authors, is bound in spiral binding. Its pages are perforated so they may be detached. Space is left between the paragraphs in the text for the writing of the laboratory notes. There are seventy-eight experiments amply illustrated with good figures. The directions to the student are good; the questions on sources of experimental error are excellent. Users of the textbook will want to consider adopting the laboratory manual.

LUKE E. STEINER

OBERLIN COLLEGE
OBERLIN, OHIO

GENERAL COLLEGE CHEMISTRY. *L. B. Richardson* and *A. J. Scarlett*, Professors of Chemistry, Dartmouth College. Henry Holt and Company, New York City, 1940. vi + 683 pp. 144 figs. 16 × 23.5 cm. $3.75.

In this second revision of Richardson's GENERAL CHEMISTRY, the authors have produced a text which is both well written and up-to-date. The most striking characteristic of the book is described in a quotation from the preface of the first edition, and repeated in the preface of this one, "The author would reiterate the belief that the *text is the vital element in chemical instruction*, and that in such books explanations more detailed than is always the case are of advantage to the student. Material of an explanatory and illustrative character, commonly confined to lectures, is therefore included in this book, which owes its length to that factor rather than to the greater number of topics treated." This additional material is smoothly woven into the more conventional subject matter and, in the opinion of the reviewer, adds greatly to the value of the book.

In conformity with the current trend in elementary textbooks, the sections on atomic structure, solutions, acids and bases, and crystal structure are given increased prominence. As these come rather early in the book, the student does not get much descriptive chemistry until he has finished at least a third of the course. Although the chapters on solution and atomic structure precede that on ionization in solution, the latter is introduced through the Arrhenius concepts, in the usual way. The general tone of the book remains conservative.

Each chapter is followed by a list of references for additional reading and a group of exercises or problems. The book has many photographs and line drawings, and an index which is commendably complete.

As in the case with all such books, there are a few mistaken or misleading statements. On the whole, however, this text is an excellent one and deserves wide adoption.

JOHN C. BAILAR, JR.

UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

THE PHYSICAL SCIENCES. *E. J. Cable*, Head of Science Department, *R. W. Getchell*, Professor of Chemistry, and *W. H. Kadesch*, Professor of Physics, Iowa State Teachers College. First Edition. Prentice-Hall, Inc., New York City, 1940. xvii + 754 pp. 300 figs. 16 tables. 15 × 23 cm. $5.00.

The purpose of this book "is to help the reader interpret intelligently the forces that make up the complex world in which he lives and to place at his disposal enough scientific knowledge to free his mind of prejudice and superstition. It should aid him to express himself accurately and to understand and appreciate scientific methods of arriving at the truth; also to form the habit of weighing values and reserving judgment until he knows all the facts."

The book treats selected topics from the general fields of physics, meteorology, chemistry, geology, and astronomy. The authors have included selected lists of reading references, corresponding to the sequence of chapters, and lists of questions covering the subject material of each of the chapters in order.

Each chapter begins with a brief historical discussion of the subject followed by a simple treatment of the technical and theoretical phases. The application of the theory to numerous practical problems is achieved through the use of a good selection of illustrative examples, problems, pictures, and diagrams. The important terms, concepts, laws, theories, and questions arising in the chapters are set apart in bold type as paragraph headings.

The treatment in general is non-mathematical, a knowledge of elementary arithmetic being sufficient to comprehend the more technical discussions. Chemical formulas and equations are also used sparingly. In general the authors have succeeded in popularizing the discussions without sacrificing scientific accuracy.

The book is modern, well edited, written in clear English, and has a pleasing, easy style. The component fields of physical science have been well integrated. The authors have shown good judgment in the selection of topics essential to a proper appreciation of our physical environment.

The book should be suitable as a text in a survey course for the liberal arts student. It should be recomended also for the lay reader.

C. S. ADAMS

ANTIOCH COLLEGE
YELLOW SPRINGS, OHIO

THE SYSTEMATIC IDENTIFICATION OF ORGANIC COMPOUNDS. A LABORATORY MANUAL. *Ralph L. Shriner* and *Reynold C. Fuson*, Professors of Chemistry in the University of Illinois. Second Edition. John Wiley and Sons, Inc., New York City, 1940. xi + 312 pp. 17 figs. 15 × 23 cm. $2.75.

"The primary purpose of courses in identification is to teach organic chemistry rather than merely to acquaint the student with a system of analysis." With this high aim, the authors have produced a most stimulating, most teachable book. "It still requires the student to exercise his own judgment at every step in the process." Numerous excellently planned questions, carefully placed throughout the volume, aid in this. For the more ambitious student, references to the original literature are given. The detailed directions, especially for the preparation of derivatives, clearly indicate that the book has had a thorough tryout in the hands of students, whose difficulties have been appreciated—and met. The writers show their knowledge of human nature and treat students as reasoning beings, not only by giving precautions, when advisable, but also by stating in some detail the reasons for them. The few adverse criticisms of the reviewer arise largely from his insistence that certain words, such as "salt," be used in a narrow, rather than a broad sense.

The book-work is excellent. It is regrettable, if after an introductory course in organic chemistry, a student should be deprived of a course based on this excellent manual.

G. ALBERT HILL

WESLEYAN UNIVERSITY
MIDDLETOWN, CONNECTICUT

ELECTRONIC STRUCTURE AND CHEMICAL BINDING. *Oscar K. Rice*, Associate Professor of Chemistry, University of North Carolina. First Edition. McGraw-Hill Book Company, New York City, 1940. xiv + 511 pp. 91 figs. 15 × 23 cm. $5.00.

For graduate students and others wanting a comprehensive book in the field of molecular structure, especially as applied to inorganic chemistry, Professor Rice's book fills a definite need. Starting with atomic theory and developing the quantum theory in some detail as applied to the hydrogen atom and to many electron atoms, the author goes on with chapters covering theories of valence, covalent and ionic bonds, the solid state, ionic crystals, complex compounds, molecular crystals, metallic crystals, and aqueous solutions.

The object of the book, according to the author, is "to see what light can be thrown on this field (inorganic chemistry) by the modern theory of the atom." Of necessity then, the book becomes "essentially a discussion of the chemical bond as exemplified in inorganic compounds."

Though the approach is not mathematical, the author makes free use of mathematical formulas to express important results, omitting details of derivation. No attempt is made to apply wave mechanical analysis in an exact manner, the semiquantitative approach being largely used, supplemented where possible by the older quantum theory. To the chemist, this approach is most acceptable.

The author devotes very little space to the concept of resonance, his reason probably being that he is dealing with inorganic not organic, compounds. However, the successful application of this concept to all fields of chemistry by Pauling suggests that it has as much value in interpreting inorganic structure as in interpreting organic structure.

In an appendix consisting of five parts, the author has gathered together some miscellaneous but valuable material aimed to help the student in acquiring a suitable basic background in classical mechanics, principles of equilibrium, nature of electrical forces, and the geometry of solid structures.

The author has done an excellent job in bringing together under one cover the many criteria bearing on molecular structure. As a reference book, as a "refresher," as a guide to any trained chemist who is willing to put in time and energy, this book has real value and plenty of "meat." Any teacher of chemistry would do well to have it on his shelf. It cannot, of course, be recommended to the inexperienced student; it is not intended for him.

SIDNEY J. FRENCH

COLGATE UNIVERSITY
HAMILTON, NEW YORK

A COURSE OF STUDY IN CHEMICAL PRINCIPLES. *Arthur A. Noyes*, Late Professor of Chemistry, California Institute of Technology, and *Miles S. Sherrill*, Professor of Physical Chemistry, Massachusetts Institute of Technology. Second Edition, rewritten. The Macmillan Company, New York City, 1938. xxv + 554 pp. 33 figs. 14 × 21.5 cm. $4.00.

This course of study, having been available in book form since 1922, is so well known that a description seems almost unnecessary. Unlike most texts in physical chemistry, the problems are not incidental to the authors' presentation but are rather the focal point about which the discussion centers. There are four hundred ninety-eight of these problems scattered through the text. They have been carefully chosen for type, ideas presented and the requirement of logical, though not too advanced, thought for solution. Possibility of mere substitution in text-developed equations is minimized. The whole idea is to stimulate the independence of thought necessary to advanced studies.

This text may be recommended without reservation for classes with sufficient background, to the mature student who wishes to work through the subject for himself, and to all teachers of physical chemistry.

M. M. HARING

UNIVERSITY OF MARYLAND
COLLEGE PARK, MARYLAND

ESSENTIALS OF COLLEGE CHEMISTRY. *G. H. Whiteford*, Professor of Chemistry, and *R. G. Coffin*, Associate Professor of Chemistry, Colorado State College. Second Edition. C. V. Mosby Co., St. Louis, Missouri, 1939. 534 pp. 32 figs. 14 × 21.6 cm. $4.00.

The authors have presented to the teaching public another textbook on general chemistry for college students, *i. e.*, "for the use of beginning college students." It embraces thirty-nine chapters, each followed by an extensive group of exercises and questions. There are three sections devoted to general review questions and exercises appropriately placed in the book. The figures and illustrations are well drawn and attractive, and the outlines are helpful and fitting. At the close, the work includes a fairly representative glossary and an appendix containing the usual tables of constants. The printing is good and typography is well selected.

A number of errors of the first edition have been corrected, but a few remain here and there. On the whole the new edition is a distinct improvement over the first and contains an entire new chapter on "Some Carbon Compounds Essential to Life Processes," and literature references have been added to the chapters in many places which add to the usefulness of the text. The use of green tinted paper is to be commended.

With such a wealth of good introductory books on the subject of general college chemistry available, one is surprised to find another text in the field offering no particularly original contribution either to the subject matter or to the pedagogy of the treatment. The general character of the book hardly seems to justify the price, in view of the more extensive treatments of the same material at a lesser cost.

HAL W. MOSELEY

TULANE UNIVERSITY OF LOUISIANA
NEW ORLEANS, LOUISIANA

ADVENTURES OF A BIOLOGIST. *J. B. S. Haldane.* Harper and Brothers, New York City and London, 1940. vii + 281 pp. 14 × 22 cm. $2.75.

If one of the ends of a scientific education is the development of the ability to see problems and to attack their solution by reasoned steps, this book is as important for the chemist to read as for the biologist. It should be a "must" on every reading list in general science.

The adventures of the biologist are adventures of the mind, and they can be made as exciting as hunting in any other jungle. The first few chapters outline many of the current unsolved biological problems. Thence the reader is led through the narrower and then the broader implications of genetics, and finally to a biological glimpse of such far fields as town-planning, politics, religious liberty, the Marxist philosophy.

Some will find in this book a vindication of belief in a classical education. The fact that the author—renowned son of a renowned father—was first educated in the classics, later passed through the stages of biochemist, physiologist, geneticist, may have something to do with the way in which this book covers a lot of territory without seeming to be superficial.

RUBBER LATEX. *H. P. Stevens*, M.A., Ph.D., F.I.C. and *W. H. Stevens*, A.R.C., Sc., F.I.C., Consulting Chemists to The Rubber Growers Association. First American Edition based on the Fourth British Edition. The Chemical Publishing Company, Inc., New York City, 1940. vi + 223 pp. 17 figs. 14 × 17 cm. $2.00 net.

While this book does not fill the need for an authoritative technical work on rubber latex, it does meet the need of an introductory outline. The book should prove of interest and value to the college student, the beginner in rubber technology, and to the non-technical rubber plant executive.

J. W. RAYNOLDS

MELLON INSTITUTE
PITTSBURGH, PENNSYLVANIA

PRINCIPLES OF CHEMISTRY. *Joel H. Hildebrand*, Ph.D., Sc.D., Professor of Chemistry, University of California. Fourth Edition. The Macmillan Co., New York City, 1940. xi + 359 pp. 48 figs. 14.5 × 31 cm. $2.50.

In the fourth edition of this well-known textbook dealing with the fundamental principles of the subject, the author has followed the same general order in the arrangement of the chapters as in the earlier editions. A chapter dealing with "Solubility" has been added. The purpose of this book is, as in the previous editions, to furnish material for the presentation of the general principles in courses intended primarily for students who have had previous training in chemistry in the secondary school. It is an essential part of the author's plan that the descriptive material necessary for the course be obtained from the companion volume, REFERENCE BOOK OF INORGANIC CHEMISTRY by Latimer and Hildebrand. The integration of the descriptive and theoretical phases of the subject and the inclusion of material necessary to make the course interesting continue to be left almost entirely to the teacher.

The object in making this revision has been "to include improvements in methods of presentation and also to bring certain portions up to date, in view of recent progress in physics and chemistry." Improvements in presentation include the insertion of sections intended to assist the student in developing better methods of study, and in gaining a more accurate idea of the scientific method and its applications. The inclusion of some material in addition to the "bare essentials" serves to make the subject more easily understandable by the student. The use of smaller type in the discussion of topics intended for only the best students, and not considered essential in the logical presentation of the subject, should simplify the task of the main group of students in the course. The terms "oxidation number" and "coördination number" are used instead of "valence" in order to avoid the confusion resulting from ambiguity.

Extensive revision has been made especially in the chapters dealing with "The Relation of Chemical Behavior to Atomic Structure," and "The Constitution of the Atom" so as to incorporate recent advances in this field. The new chapter on "Solubility" contains an exposition of a few of the basic ideas connected with this field and is intended for supplementary reading. A brief discussion of the "Proton Donor-Acceptor" and the "Electron Donor-Acceptor" systems of acids and bases is included, even though these find little application in the text discussion, and the system based on the hydrogen and hydroxide ions is commonly employed. This will serve to give the student the important idea, so frequently overlooked even by teachers of science, that more than one interpretation may be possible and desirable, and that the one which is most useful is the most acceptable.

The exercises are well planned to require an understanding of the principles which they illustrate.

The revision of this textbook has been done in a very able manner, so that the book in its fourth edition will continue to prove valuable in courses in which emphasis is placed on fundamental principles. It is not suited to use in the course intended to afford a survey of a broad field or to place emphasis on industrial applications. The teacher who prefers the flexibility afforded by separate texts in the descriptive and theoretical phases of the subject to an author's development of a correlated course will find in this book a scholarly presentation of the subject.

STUART R. BRINKLEY

YALE UNIVERSITY
NEW HAVEN, CONNECTICUT

PROCEEDINGS OF THE SEVENTH SUMMER CONFERENCE ON SPECTROSCOPY AND ITS APPLICATIONS (Massachusetts Institute of Technology). Edited by *G. R. Harrison*. The Technology Press. Distributed by John Wiley and Sons, Inc., New York City, 1940. viii + 154 pp. 71 figs. 19 × 25 cm. $2.75.

FRITZ FEIGL (1891–)

Contributed by Ralph E. Oesper, University of Cincinnati

(For biographical sketch of Fritz Feigl, see page 538.)

Editor's Outlook

WE HAVE tried to serve our readers among the students and teachers by publishing from time to time articles describing the construction of "homemade" laboratory apparatus. We have been led to wonder if this has gone a little too far. At any rate, we recently received a suggestion that the construction and use of such "substitutes" deprive students of the opportunity to use and appreciate truly modern types of equipment.

It would seem that there are two distinct considerations involved. No one would deny that the ingenuity which a youngster shows in building and equipping his own laboratory out of odds and ends is a thing to be commended and encouraged, but he must eventually come to the point where he needs a wider viewpoint. He will never be a real chemist until he acquires some facility with the best tools of his profession.

One of our professors of physical chemistry used to maintain that by the time a piece of apparatus got into the hands of the instrument makers all the interesting work with it had been done. On the other hand, there may even be those who find it fascinating to turn the crank of an adding machine. Still, it is a safe pedagogical principle that when a student has designed and built his own apparatus he is at least more likely to understand the principles upon which it operates. We recently heard a laboratory course described in which the first exercise was on the bunsen burner. After inspecting one and taking it apart, each student constructed one of his own out of glass tubing and then proceeded to use it for the next few experiments. We dare say that none of these students will later attach the wrong end of the burner to the gas supply—as we have seen at least one other do.

A student is entitled to a feeling of confidence in his ability to solve his problems—instrumental as well as theoretical—by the sweat of his brow and the dexterity of his hands. But the pedagogical argument is not all on the one side. Every well-trained chemist must have an opportunity, at some stage in his training, to see what modern instrumental equipment will do. We often hear a man say: "I don't keep a lot of facts in my mind, but I know where to go to find them." To about the same extent is one justified in knowing where to *buy* apparatus when he is unable to make it. In neither instance can one entirely avoid the personal responsibility.

It is probably in the courses in physical and advanced analytical chemistry that the student gets his best chance to become familiar with proper instruments. Perhaps a reasonable rule to follow would be: When the emphasis is on the accuracy of results the student should be furnished with the best modern apparatus available; when it is on the principles involved the student may possibly learn more by building or assembling his own apparatus.

We wonder how our readers feel about "homemade" apparatus.

WE TAKE pleasure in announcing the appointment of Dr. Aubison T. Burtsell, of the College of the City of New York, as associate editor in charge of Trade Announcements.

AN EXAMPLE of the inconsistencies often met in the use of the terms "acid" and "base" is to be found in the explanations given for the exchange reactions of the zeolites and artificial resins used in water softening. The substitution of Na for Ca has long been called "base exchange," and similar exchanges of "acid ions" (*i.e.*, negative ions) are also known. The difficulty is seen in a quotation from a recent article on "Base Exchange Resins": "The base exchange resins remove the metal ions from the water, forming mineral acids. In removing the acid radicals, the acid exchange resins liberate hydroxyl ion, which neutralizes the hydrogen ion previously formed."

In other words, when hydrogen ions are substituted for Ca, an acid ion (hydrogen) is exchanged for a base (Ca)! And on the other hand, the hydroxyl ion (which certainly no one has ever regarded as anything but strongly basic) is substituted for so-called "acid ions"—presumably such negative ions as sulfate, etc.

Of course, the more consistent modern usage would reverse the classification of positive and negative ions, in regard to their respective acidic and basic properties. Calcium, and other metal ions, are acids, and their substitution by the positive hydrogen ion is no great strain on one's sense of the fitness of things. At the same time, all negative ions, being proton-acceptors, are *bases* (not "acid ions"), and the exchange of hydroxyl for sulfate is not—as one would otherwise be led to suppose—a mysterious substitution of a base for an acid.

LIME *and* LIME KILNS

EUGENE W. BLANK

Colgate-Palmolive-Peet Company, Jersey City, New Jersey

UNDOUBTEDLY one of the first chemical discoveries of ancient man was lime. Once man had progressed to the point of using fire and building fireplaces the discovery was impendent, for it was inevitable that eventually he would unwittingly employ limestone in the construction of his hearth, with the resultant production of lime. Many years must have passed, however, before he learned to utilize the valuable properties of lime in the arts and crafts of his time.

If limestone is heated to dull redness (approximately 550°C.) it begins to decompose, liberating carbon dioxide and leaving a residue of calcium oxide or quicklime as it is more generally known. In a closed container the decomposition stops when the pressure of the carbon dioxide reaches a point known as the dissociation pressure. This dissociation pressure has a definite value at each temperature and under such conditions the system is in equilibrium. When the reaction is carried out in an open vessel so that the carbon dioxide can readily escape, the reaction goes practically to completion. If steam is passed through the vessel, decomposition occurs still more readily. The process of heating limestone to procure quicklime is known as lime burning and the open vessels employed for lime burning are called kilns.

The literature on the subject of lime burning is immense. Spackman (*1*) alone mentions approximately two hundred ninety authoritative writers on lime and cement from the earliest to the present period. Generally speaking, lime burning did not properly constitute an industrial process until about the middle of the past century. Prior to that period lime burning was carried on to supply the lime burner's own immediate needs and purely local requirements, and even today some lime is being produced under such a status.

Probably the paramount reason lime, for so many years, was utilized in close proximity to the kiln in which it was produced was due to the difficulty and danger of storing and transporting it. The advent of barrels, and particularly the steel drum, together with the development of the modern continuous kiln spelled the epilogue of what was once a flourishing chemical operation carried on in thousands of localities. In many sections of this country there was a homemade rock "pot" kiln on almost every farm of any size, but today the great majority of these kilns have been abandoned and are rapidly disintegrating and disappearing.

Cato (B.C. 234–149) is the first writer mentioned by Spackman (*2*). Cato, after he had attained fame and fortune by serving the Roman state in both civil and military life, continued to maintain his interest in agriculture. His *De Re Rustica* is essentially a treatise on farming, but it contains a few paragraphs on lime burning. The shape and dimensions of lime kilns are given and also the precautions to be observed in burning limestone to obtain a good quality product. Cato gives the dimensions of a kiln as ten feet wide and twenty feet deep, tapering to three feet wide at the top of the furnace (*3*). Cato proceeds to give instructions regarding the proper operation of the kiln and points out that continual watch is necessary to prevent the fire in the kiln from consuming itself. As white a stone as possible should be put in the kiln, and the burning is complete when a less smoky flame comes out of the top of the kiln.

FIGURE 1.—AN OLD KILN RESTORED TO ITS ORIGINAL CONDITION. THE LINE OF DEMARCATION BETWEEN THE OLD AND NEW STONE CAN BE READILY SEEN IN THE PHOTOGRAPH

Vitruvius, a celebrated Roman engineer and architect, lived during the reign of Augustus (B.C. 27–A.D. 14). In Book II of his famous *De Architectura*, Chapter Five treats of lime. Vitruvius stresses the point that a white stone should be used in the production of lime (*4*), " . . . with regard to lime we must be careful that it is burned from a stone, which, whether soft or hard,

is in any case white. Lime made of close-grained stone of the harder sort will be good in structural parts; lime of porous stone, in stucco . . . "

Vitruvius goes on to explain why lime becomes solid when mixed with water and sand and finally makes the significant observation (*5*) that " . . . limestone when taken out of the kiln cannot be as heavy as when it was thrown in, but on being weighed, though its bulk remains the same as before, it is found to have lost about a third of its weight[1] owing to the boiling out of the water."

FIGURE 2.—A MULTIPLE LIME KILN. THE KILNS SHOWN IN FIGURE 1 AND FIGURE 2 HAVE BEEN RESTORED TO THEIR ORIGINAL CONDITION BY THE CITY OF ALLENTOWN, PENNSYLVANIA. THE KILNS ARE SITUATED SOUTHWEST OF THE CITY ALONG THE LITTLE LEHIGH PARKWAY WHICH HAS RECENTLY BEEN MADE INTO A CITY PARK

Attention was early directed to the baffling (and dangerous) chemical proclivities of lime. In this connection Pliny (A.D. 23–79) wrote (*6*), "We cannot fail to marvel that a material which has been already burned, is again inflamed by water." The chemical knowledge of the Greeks and Romans was not sufficiently advanced to explain the phenomenon of slaking, but they utilized lime widely in the construction of buildings. Pliny complains of the collapse of many such structures and bluntly points out the cause, "The chief causes of the collapse of so many buildings in Rome is the pilfering of lime, as a result of which stone is laid on stone without proper mortar. The older the slurry is, the better. The building laws of our ancestors contained a provision that contractors should use no mortar less than three years old, which explains why their stucco has never spoiled by cracking."

Pliny has little to say concerning the burning of lime and in general his observations on lime are largely a recapitulation of what Vitruvius and others had previously written on the subject.

We have seen that Vitruvius considered the properties of lime to be engendered by the loss of water during the burning operation. As a matter of fact the chemical change which occurs during the conversion of limestone into caustic lime was not really understood until J. Black in 1777 at Edinburgh published his celebrated thesis, "Experiments upon Magnesia Alba, Quicklime, and other alcaline substances."

Lime burning became a quite common operation in and around London during the Middle Ages when stone buildings were being erected in increasingly large numbers. The vendors of lime tended to congregate in one section of the city and Sea Coal Lane, near Ludgate Circus, was often referred to as "Limeburners Lane" for a great part of the colliers' business was with those who required fuel for kilns (*7*). From about 1200 to 1300 the use of coal was restricted in general to iron-working and lime burning, because the absence of chimneys rendered it unsuitable for use as a household fuel.

Whenever sizable building operations were undertaken, and correspondingly large quantities of lime were required, it was customary to build lime kilns adjacent to the building site. These kilns were usually small and temporary structures.

Where lime was burnt for sale and not for use on the spot, the kilns were usually of larger capacity and more substantially constructed. A sixteenth-century account of the erection of eight such kilns at an unspecified locality—probably Calais—records that each kiln was twenty feet high, with walls ten feet thick, and an average internal breadth of ten feet, and cost over 450£ (*8*).

Lime was burnt in this country at Providence, Rhode Island, as early as 1661 and carried into Boston. In 1723 a lime kiln was put into operation near the Bowling Green in Boston. Previously, in 1697, considerable excitement had been occasioned by the discovery of limestone in Newbury, Massachusetts (*9*).

In outlying sections, early in the history of our country, it was usual for each farm to have its own kiln, which was in most cases a solid stone structure built against a hill so that it could be readily filled from the top with limestone. Such an arrangement also materially strengthened the kiln and helped to insulate and conserve the heat during the lime burning. In general pot kilns were about twenty feet deep, about six feet in diameter at the top widening to a diameter of about seven feet and then contracting to about two feet by a foot and one-half at the bottom where there

[1] The theoretical loss of pure calcium carbonate would be 43.96 per cent.

was an opening in the side about eighteen inches square known as the "eye" or "draw-hole" (*10*).

The kilns were usually lined with a fire-resistant stone found in the vicinity. Usually no grate was used, the kiln being filled with alternate layers of stone and wood. A quantity of brushwood interspersed with the lower layers permitted ignition of the fuel used in the kiln.

If the kiln was provided with a grate a layer of wood was laid on the grate. Over this was erected an arch of large stones, considerable space being left between the stones. This arch supported the balance of the stone with which the kiln was subsequently filled. The stone was packed sufficiently loosely to permit a good draft.

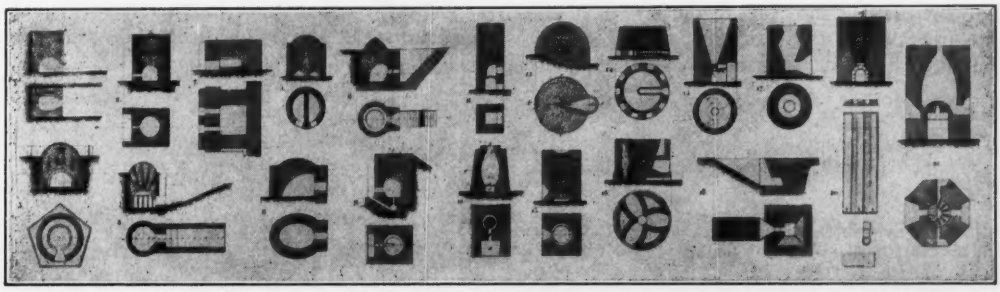


FIGURE 3.—A PLATE OF PARTICULAR INTEREST AS SHOWING THE GREAT VARIETY OF SHAPES A SIMPLE POT KILN CAN HAVE. TAKEN FROM THE "NOUVEAU MANUEL DU CHAUFOURNIER" BY BISTON (*14*)

The wood was ignited and as it was consumed was replenished from time to time. No very reliable method for determining when the limestone was completely burnt existed. The shrinkage of the contents of the kiln provided some indication to an experienced lime burner. Another indication was the ease with which an iron bar could be inserted into the kiln, as limestone upon burning becomes relatively softer, but this method failed in case the stone burned to a hard, dense lime. Most operators were content to allow the kiln to burn for a period of about seventy-two hours, trusting to luck that in this length of time the stone would be completely converted into lime.

These kilns were exceedingly wasteful of fuel, since the kiln was allowed to cool down each time a batch of lime was produced. Production also was quite limited.

Through the course of many years lime kilns have taken every conceivable shape, usually with the object of improving the quality or quantity of lime produced from a given weight of fuel. As a result of this empirical testing it has been found that, generally speaking, the shape of a simple pot kiln is of secondary importance.

Another method utilized in burning lime was the open pile method. In some districts in Pennsylvania the burning is still done in this fashion by stacking alternate layers of wood or soft coal and blocks of limestone so arranged as to cause a good draft through the pile. After the fuel is well ignited earth is thrown over the pile. It is reported that open heap burning can still be observed south of Frogtown in Clarion County and close to Ford City in Armstrong County, both in Pennsylvania (*11*).

Although, as already indicated, lime has been burned in thousands of places in this country, certain localities have been especially favored by the quantity, and particularly the quality, of limestone available and their strategic location as shipping centers.

Lime was produced in Maine very early, probably about 1733. "Samuel Waldo, of Boston, having by purchase or inheritance from his father, obtained a title in the lands of the St. George and Medomac rivers: having made experiments upon the limestone found near the river at what is now called the prison quarry, and finding it good, he caused a new lime kiln to be erected, and lime burnt in considerable quantities for the Boston markets" (*12*).

By 1835 the annual production in the state had increased to nearly three-quarters of a million casks.

Rockland, Maine, soon took the lead as a lime center. In this locale the limestone was formerly brought by ox or horse team to kilns located conveniently close to the harbor.

From Rockland harbor lime was shipped by schooner to all points. The parallel activity of bringing in wood to feed the kilns engaged more sailing vessels than the actual shipping of the lime itself. A peculiar style of short stumpy boat known as "Saint John Woodboats" gradually evolved. These vessels were close-reefed to permit raising the booms above high deck loads, and from the wide, flat stern devoid of any semblance of overhang usually hung a yawl boat. Many of these wood boats had no bowsprits.

These vessels were quite often tremendously overloaded and burdened with enormous deckloads, but losses by sinking were generally rare due to the buoyancy of the cargo, although vessels not infrequently sailed slowly into port with the helmsman standing knee-deep in water (*13*).

On the other hand, exporting lime from Rockland required staunch and dry vessels due to the dangerous nature of the cargo. Many of these lime schooners became world famous and are still remembered by name to this day.

Occasionally a vessel sprang a leak and the heat of the lime reacting with the water started a fire. Smothering the conflagration was the only salvation. A cask of lime was speedily broached, its contents made into a thick paste with water and all the crevices and cracks in the deck and around the hatches were plastered shut. The vessel was then turned toward the nearest port while the crew labored and waited in suspense.

Sometimes the fire was readily smothered; then again the vessel often lay "sealed up" in harbor for months before the fire died out or it was decided to scuttle the ship. Sinking the vessel was sure to extinguish the fire but the swelling lime casks usually burst the vessel's sides with total loss of the boat so that scuttling was resorted to only as a kill-or-cure measure.

Of all the bustling activity incident to lime burning "down on the farm" little remains today. Production and transportation have both lost their old-time glamor. Rockport lime is now sealed in metal drums and towed in steel barges. The average pot kiln is but a picturesque ruin that evokes rich memories only in one who can recall a midnight horizon lit with the glow of myriad neighboring kilns.

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A FRESHMAN EXPERIMENT: PREPARATION AND PROPERTIES OF ETHYLENE

GUIDO H. STEMPEL, JR.

Carnegie Institute of Technology, Pittsburgh, Pennsylvania

THE method for preparing small quantities of ethylene described here requires little apparatus, a minimum of time, and is safe enough and simple enough to be used in the freshman laboratory. This makes it feasible for first-year students to prepare ethylene and to compare its properties with those of methane and acetylene, for which simple methods of preparation are well known.

This synthesis of ethylene proceeds according to the equation:

$$C_2H_4Br_2 + Zn = ZnBr_2 + C_2H_4$$

The reaction is most easily carried out in a 50-cc. Erlenmeyer flask equipped with a gas-delivery tube. The following amounts of reactants are sufficient to prepare about 250 cc. of ethylene: one cc. of ethylene bromide (2.18 g.), 1.5 g. of Zn dust (excess), and five cc. of alcohol. After the reactants are mixed there is an induction period, sometimes as long as three minutes, before the reaction starts. The induction period can be considerably reduced by warming the mixture to about 60°C. Once the reaction begins it proceeds smoothly without further heating or attention and at such a rate that the ethylene is easily collected over water in test tubes. The middle fraction of the ethylene so prepared is better than 95 per cent pure.

Ethylene can be used to demonstrate the usual properties of olefins. For example, it rapidly decolorizes a one per cent aqueous solution of potassium permanganate as well as a one per cent solution of bromine in either CCl_4 or water. A simple instructive experiment is to invert one test tube of ethylene in a beaker of water and a second in a beaker of bromine water. The gas slowly reacts with the bromine to form liquid products, thus permitting the water to rise in the test tube. By agitating the test tube the absorption can be completed in about ten minutes. The tube of ethylene inverted in the beaker of water shows no change.

In general, the laboratory preparation of large quantities of ethylene is more economically carried out by the standard method of alcohol dehydration. When only small quantities are required, the simplicity of the preparation from ethylene bromide gives this method preference.

WHY NOT MODERNIZE *the* TEXTBOOKS ALSO?

II. Hydrolysis and Its Relation to Ionic Charge and Radius

LAURENCE S. FOSTER

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AT THE Baltimore meeting of the American Chemical Society, in his contribution to the symposium on "Theories and Teaching of Acids and Bases," Professor Briscoe reminded us that in this connection it is the duty of teachers of chemistry to present the student with all the pertinent facts as well as the various theories which have been advanced for their interpretation. "With all the facts before him, the student can then examine critically *all* theories that have been offered to explain the chemical characteristics and reactions of acids and bases."[1] Surely, few will disagree with this. How does it happen, then, that seventeen years after the publication of the Brønsted-Lowry viewpoint, textbooks still introduce the concept of proton-transfer only half-heartedly into their discussions of *neutralization*, and fail entirely to point out its application to an equally important converse process, *hydrolysis?* Apparently, this topic presents to textbook writers what appear to be insuperable difficulties, and almost as a group they revert to the admittedly simpler, but less logical, earlier viewpoint. The answer lies, I believe, in the failure of authors to follow the precepts expressed by Professor Briscoe. If *all* the pertinent facts were made available, the student would have no more difficulty in understanding the modern theory of hydrolysis than he has with other aspects of acid-base equilibria. It is possible that because of its difficulty the topic of hydrolysis has no place in textbooks designed for students who are studying chemistry for the first time, but if it is included and theories to explain it are discussed, certainly the explanations should be consistent with the treatment afforded other equilibria existing in aqueous solutions. The purpose of this article is to summarize an approach based upon recently evolved ideas concerning atomic structure, crystalline solids, complex compounds, strong electrolytes, and acids and bases which enable one to treat hydrolytic phenomena systematically.

As has often been pointed out, to modernize the approach to the theory of electrolytic solutions one must do more than change a few words in his lecture notes. The end to be reached must be anticipated from the first day of the course. Before investigating the theories of hydrolysis, the student needs to possess a knowledge of what constitutes a salt; what happens when salts dissolve in a polar solvent; why water is such an unusual liquid; by what processes the ions of the salt become hydrated; and what is meant by acidic and basic properties. He should, thus, be familiar with the fundamental concepts in the modern theory of electrolytic solutions. These topics have received adequate treatment in many articles which have appeared in the JOURNAL OF CHEMICAL EDUCATION and elsewhere, as well as in numerous textbooks.[2] An equally important topic, but much less frequently mentioned, is the influence of the size of ions and the magnitude of their charge upon the properties of the compounds containing them.[3] Attention might also be focused upon the idea of ion-deformation or polarization, but this phenomenon is still somewhat obscure and produces only secondary effects upon the tendency toward hydrolysis. If the course is developed so that these fundamental topics are logically presented, no difficulty need be anticipated in extending the viewpoint to the study of hydrolytic phenomena.

WHAT HAPPENS WHEN SALTS DISSOLVE?

When salts come in contact with a solvent with a high dipole moment, the crystal lattice is broken down, the individual positive and negative ions become surrounded by clusters of solvent molecules, and the forces of attraction between the ions are reduced.[4] The explanation of the reactions of salts in aqueous solution must take into account the formation of hydrated ions.

FORCES OF ATTRACTION BETWEEN THIRD PERIOD POSITIVE IONS AND WATER MOLECULES

Latimer and Hildebrand[5] have tabulated the forces exerted by the positively charged central ion upon the negative end of attached water dipoles and have shown that in passing from sodium to chlorine, as the radius of

[1] BRISCOE, "Teaching the new concepts of acids and bases in general chemistry," J. CHEM. EDUC., **17**, 128 (1940).

[2] See particularly, HILDEBRAND, "Principles of chemistry," 4th ed., The Macmillan Company, New York City, **1940.** Chapters 5, 8, 13, 18 (§25–6), 20 (§13, 14, and 15).

[3] HILDEBRAND, *op. cit.*, pp. 268–72; CARTLEDGE, "Introduction to inorganic chemistry," Ginn and Company, Boston, **1935,** Chapters 8 (§15 and 16), 14 (§19), and 22 (§52–7).

[4] FRENCH, "Some uses of the polar molecule concept in elementary chemistry," J. CHEM. EDUC., **13,** 122 (1936), especially 3, p. 127; HUGGINS, "Some contributions of crystal structure research to general chemistry teaching," *ibid.*, **13,** 160 (1936), especially p. 161, "Ions."

[5] LATIMER AND HILDEBRAND, "Reference book of inorganic chemistry," revised ed., The Macmillan Company, New York City, **1940,** p. 27.

the *kernel* becomes smaller and the ionic charge greater, the force of attraction rises tenfold, due to coulombic forces alone.

The number of attached water molecules, furthermore, is related to the size of the central ion and, for the third period elements, may be six or four. Other water molecules may be attached in a secondary layer, but the influence of the charge of the central ion upon them is negligible. It is instructive to examine the consequences of these increasingly strong forces of attraction of the central kernel for the oxygen ion of the attached molecules of water of hydration. In the structure $[Na(H_2O)_6]^{1+}$, the forces are so weak that little distortion of the water molecule may be detected; they are not much different in structure from unattached water molecules. $[Mg(H_2O)_6]^{2+}$ shows slightly acidic properties, due to the weakening of the bond holding the protons, but hydrolysis of magnesium salts is almost negligible. In the hydrated aluminum ion, $[Al(H_2O)_6]^{3+}$, the oxygen of the water molecules is held much more firmly to the Al kernel, due to the diminished distance between them and the increased charge. The protons attached to the oxygen ions, moreover, are repelled by the high charge of the Al kernel, and the bond holding the protons becomes so weakened that the ion, $[Al(H_2O)_6]^{3+}$, can act as a proton donor and is thus a weak acid. If we may assume the temporary existence of such hypothetical ions as $[Si(H_2O)_4]^{4+}$, $[P(H_2O)_4]^{5+}$, $[S(H_2O)_4]^{6+}$, and $[Cl(H_2O)_4]^{7+}$, we should expect increasing acidity in passing from silicon to chlorine. Protons would be removed with increasing ease, resulting in the formation of the following well-known structures, which are stable in aqueous solutions of a pH of 7:

$[Si(OH)_4]^0$, $[(HO)PO_3]^{1-}$, $[SO_4]^{2-}$, and $[ClO_4]^{1-}$.

IONIC POTENTIAL

Cartledge has applied the term *ionic potential*, ϕ, to the ratio of the charge of the ion to its radius, and has found that the acid-base properties of elements depend linearly upon the square root of this parameter.[6] Thus, for kernels with values of $\sqrt{\phi}$ below 2.2, the hydrated ions are not appreciably acidic; for those of $\sqrt{\phi}$ values between 2.2 and 3.2, the hydrated ions are weakly acidic and the corresponding hydroxides are amphiprotic; and for those of $\sqrt{\phi}$ values above 3.2, the hydrated ions and the corresponding hydroxides are both acidic. The ionic potential, as defined, does not take into account the polarization of the ions, and is, therefore, only approximate in its application. Even though for zinc the value of ϕ is less than for magnesium, the hydrated zinc ion, $[Zn(H_2O)_6]^{2+}$, is more acidic than the hydrated magnesium ion, $[Mg(H_2O)_6]^{2+}$. This discrepancy may be traced to the presence in the zinc kernel of a completed shell of eighteen electrons, rather than eight. The ionic potential is nevertheless successful in predicting the broad periodic variations in acid-base properties of the elements; in explaining why in a given series of the *transitional elements*, when the radii are practically constant, the acid-base properties depend largely upon the valence; and for a single element, why the hydrated ions become increasingly acidic as the state of oxidation rises.

In Table 1, the *crystal ionic radii* and the *ionic potential*, ϕ, are given for the ions of all the *normal* elements, both *a* and *b*, in Groups I, II, and III of the Periodic Table. The ones which retain water of hydration when their salts crystallize from aqueous solution are seen to be those of small ionic radius. Those with large values of the ionic potential are distinctly acidic.[7] The increasing polarizing effect of the 18-electron kernel elements is established by the earlier appearance of acidic properties in the hydrated ions of this series. All of the *b* elements listed, furthermore, may serve as the central atom in complex anions, a property which characterizes markedly only the last four of the *a* elements listed.

TABLE 1

IONIC POTENTIALS FOR NORMAL CATIONS

a-Group Elements (8-Electron Kernel)				*b-Group Elements (18-Electron Kernel)*			
Ion	*Radius* A.*	*φ†*		*Ion*	*Radius* A.*	*φ†*	
Cs^{1+}	1.69	0.59					
Rb^{1+}	1.48	0.68					
				Au^{1+}	1.37	0.73	
K^{1+}	1.33	0.75					
				Ag^{1+}	1.26	0.79	
				Cu^{1+}	0.96	1.04	
Na^{1+}	0.95	1.05					
Ba^{2+}	1.35	1.48					
Li^{1+}	0.60	1.67					
Sr^{2+}	1.13	1.77					
Ca^{2+}	0.99	2.02		Hg^{2+}	1.10	1.82	
La^{3+}	1.15	2.60		Cd^{2+}	0.97	2.06	
Mg^{2+}	0.65	3.04		Zn^{2+}	0.74	2.70	
Y^{3+}	0.93	3.23		Tl^{3+}	0.95	3.16	
Sc^{3+}	0.81	3.70		In^{3+}	0.81	3.70	
Al^{3+}	0.50	6.00		Ga^{3+}	0.62	4.84	
Be^{2+}	0.31	6.45					
B^{3+}	0.20	15.00					

Ions are hydrated; Ions are increasingly acidic

Ions are hydrated; Ions are increasingly acidic

* Crystal radii of ions are those given by PAULING, "Nature of the chemical bond," 2nd ed., Cornell Univ. Press, Ithaca, New York, 1940, p. 346.

† ϕ = charge ÷ radius, the Ionic Potential.

DEFINITION OF HYDROLYSIS

In aqueous solutions, hydrolysis of a salt consists of the reaction of either or both the anion or the cation with water. The reactions are independent of each other and whether the pH of the solution, as a result of these reactions, will have a value equal to, greater than, or less than 7, will depend upon the net effect of the reactions of all the ionic or molecular species present.[8] For example, solutions may be acid due to the presence of an acidic cation, like ammonium, NH_4^{1+}, which may be more strongly acidic than the accompanying anion is basic. If the anion is also moderately basic, as in ammonium acetate, the solution may be neutral even though the salt is extensively hydrolyzed. The solution, on the other hand, may be acidic due to the presence of an anion which is itself an acid, as with sodium bisulfate, $Na^+(HSO_4)^-$. Alkaline solutions result when

[6] CARTLEDGE, *J. Am. Chem. Soc.*, **50**, 2855–72 (1928); *Cf.* CARTLEDGE, "Introduction to inorganic chemistry," *loc. cit.*, p. 302.

[7] EMELÉUS AND ANDERSON, "Modern aspects of inorganic chemistry," D. Van Nostrand Co., New York City, 1938, pp. 154–65 (Water of crystallization); pp. 165–78 (Nature of the coordinate linkage).

[8] MIDDLETON AND WILLARD, "Semimicro qualitative analysis," Prentice-Hall, Inc., New York City, 1939, Chapter 9; Chapter 13, p. 237, etc.

the cations or anions are more strongly basic than the conjugate substances are acidic. The terms *acid* and *base* are no longer restricted to describe neutral molecules but may be applied to positively charged ions, neutral molecules, or negatively charged ions, if they act as acids or bases in the particular mixture under consideration, and *hydrolysis* refers to reactions in which water enters as an active reagent.

APPLICATION OF THE MODERN VIEWPOINT TO THE STUDY OF THE HYDROLYSIS OF THE CHLORIDES OF THE THIRD PERIOD METALS

Hydrolysis of Aluminum Chloride—Reaction of the Hydrated Aluminum Ion with Water

If we dissolve anhydrous $AlCl_3$ in water, it immediately becomes hydrated and from the solution, under suitable circumstances, we are able to crystallize $AlCl_3 \cdot 6H_2O$ which could be written $[Al(H_2O)_6]^{3+} \cdot 3Cl^-$. That is, in the crystal lattice the Al kernel is found to be surrounded by 6 molecules of water and is entirely separate from the Cl^- ions which are located in adjacent parts of the crystal. When $AlCl_3 \cdot 6H_2O$ is dissolved in water, the solution is found to test acidic by the use of litmus or other indicators. This is explained by the idea that the $[Al(H_2O)_6]^{3+}$ ion is an acid and has reacted as follows with water:

$$[Al(H_2O)_6]^{3+} + H_2O \rightleftarrows H_3O^{1+} + [Al(OH)(H_2O)_5]^{2+}$$

And perhaps in a second reaction:

$$[Al(OH)(H_2O)_5]^{2+} + H_2O \rightleftarrows [Al(OH)_2(H_2O)_4]^{1+} + H_3O^{1+}$$

This reaction does not go any farther, evidently, since $[Al(OH)_3(H_2O)_3]^0$, aluminum hydroxide, an insoluble substance, does not precipitate. In other words, H_2O as a base is not strong enough to remove more than two protons from each molecule of the acid $[Al(H_2O)_6]^{3+}$.

If we add NaOH, we observe the precipitation of aluminum hydroxide, $[Al(OH)_3(H_2O)_3]^0$, and upon addition of excess NaOH, disappearance of the precipitate. This is explained by the fact that the OH^{1-} ion is a much stronger base than the H_2O molecule and can remove enough protons from the $[Al(H_2O)_6]^{3+}$ ion first to cause the precipitation of $[Al(H_2O)_3(H_2O)_3]^0$ and then, upon addition of more OH^{1-} ions, to dissolve the amphiprotic aluminum hydroxide precipitate. The hydrated aluminum ion continues to act as an acid and loses protons until it finally arrives at a structure having the composition $[Al(OH)_6]^{3-}$.

If hydrochloric acid is added to the solution of sodium aluminate, which contains, thus, hydrated Na^+ ions, which we may neglect, and $[Al(OH)_6]^{3-}$ ions, the precipitate $[Al(H_2O)_3(OH)_3]^0$ reappears. Upon addition of more hydrochloric acid, the precipitate dissolves again, due to the formation of $[Al(H_2O)_6]^{3+}$ according to the following ionic equations:

$$3Na^{1+} + [Al(OH)_6]^{3-} + 3H_3O^{1+} + 3Cl^{1-} \rightleftarrows [Al(OH)_3(H_2O)_3]^0 + 3H_2O + 3Na^{1+} + 3Cl^{1-}$$

$$[Al(OH)_3(H_2O)_3]^0 + 3H_3O^{1+} + 3Cl^{1-} \rightleftarrows [Al(H_2O)_6]^{3+} + 3Cl^{1-} + 3H_2O$$

The final solution contains, in addition to the $[Al(H_2O)_6]^{3+}$ ions, $[Na(H_2O)_6]^{1+}$ ions (written simply Na^{1+} in the equations) and an equivalent number of hydrated Cl^{1-} ions.

Hydrolysis of the Chlorides of Magnesium and Silicon

The magnesium ion, $[Mg(H_2O)_6]^{2+}$, is so weak an acid that only two protons are lost even in the presence of excess of the strongly basic OH^{1-} ion. Consequently, $[Mg(H_2O)_4(OH)_2]^0$ is precipitated on the introduction of sodium hydroxide solution into a solution of $MgCl_2 \cdot 6H_2O$, but is not redissolved on the addition of excess NaOH. $SiCl_4$, on the other hand, is completely hydrolyzed when it comes in contact with water, due to the fact that the silicon ion, $[Si(H_2O)_4]^{4+}$, is distinctly acidic and loses four protons to water molecules which are sufficiently basic to take them. Addition of sodium hydroxide solution causes the disappearance of the precipitate of silicic acid in accordance with the following ionic equation:

$$[Si(OH)_4]^0 + 4Na^{1+} + 4OH^{1-} \rightleftarrows [SiO_4]^{4-} + 4H_2O + 4Na^{1+}$$

Reaction of NH_4Cl with Sodium Aluminate

The explanation of the formation of a precipitate of $[Al(OH)_3(H_2O)_3]^0$ on the addition of NH_4Cl to a solution of sodium aluminate is as follows: The NH_4Cl solution contains the ions NH_4^{1+} and Cl^{1-}, in addition to the ions H_3O^{1+} and OH^{1-} which are always present to a very small extent in H_2O. The NH_4^{1+} ion is a fairly strong acid and if present in sufficient quantities can cause the precipitation of $[Al(OH)_3(H_2O)_3]^0$ by giving up protons to the aluminate ion, $[Al(OH)_6]^{3-}$, according to the equation:

$$3Na^{1+} + [Al(OH)_6]^{3-} + 3NH_4^{1+} + 3Cl^{1-} \rightleftarrows [Al(OH)_3(H_2O)_3]^0 + 3Na^{1+} + 3NH_3 + 3Cl^{1-}$$

The NH_4^{1+} ion is not sufficiently acidic, however, to cause the precipitate to redissolve and form $[Al(H_2O)_6]^{3+}$.

Prevention of Precipitation of Magnesium Hydroxide by Addition of Ammonium Chloride

It is well known that addition of an aqueous solution of ammonia, NH_3, will precipitate $[Mg(H_2O)_4(OH)_2]^0$ from solutions of magnesium salts, but that the presence of ammonium chloride in the ammonia solution will prevent the formation of the precipitate. Aqueous ammonia solution contains as bases ammonia molecules and a very small percentage of hydroxyl ions which are formed in the reversible reaction:

$$NH_3 + H_2O \rightleftharpoons [NH_4]^{1+} + [OH]^{1-}$$

which proceeds to the right to only a very slight extent. There are, however, enough basic particles present (both NH_3 and OH^{1-}) to remove two protons from each of the $[Mg(H_2O)_6]^{2+}$ ions and cause precipitation of $[Mg(H_2O)_4(OH)_2]^0$. Addition of ammonium chloride to the aqueous ammonia solution causes the concentration of the strongly acidic ammonium ions, NH_4^{1+}, to be greatly increased. They furnish protons to any basic ions and molecules present in the magnesium solution

and counteract the effect of the ammonia molecules. The same result would be obtained by the addition of dilute hydrochloric acid to the mixture. As a consequence the formation of the basic hydrated magnesium hydroxide is prevented.

THE ACID-BASE PROPERTIES OF MANGANESE DERIVATIVES

Manganese may exist in states of oxidation of 1+, 2+, 3+, 4+, 6+, and 7+. For each of these valences, and depending upon the coördination number and the type of linkage involved, there is a corresponding ionic radius. In general, the higher the charge of the ion, the smaller is its radius; so with Mn^{2+}, C.N. = 6, we have an ion of fairly low charge and a radius of 0.91 A.; with Mn^{3+}, the radius is 0.7 A.; for Mn^{4+}, 0.52 A.; for Mn^{7+}, 0.46 A.[9] Since the radius and the charge of the Mn^{2+} ion are about the same as for the Zn^{2+} ion, r = 0.74 A., the hydrated ions, $[Mn(H_2O)_6]^{2+}$ and $[Zn(H_2O)_6]^{2+}$, are of approximately the same acidity, and, while hydrolysis occurs, it does not proceed very far. On the other hand, the $[Mn(H_2O)_4]^{7+}$ ion is so acid that all of the protons are repelled, and the structure degenerates to produce the familiar permanganate ion, $[MnO_4]^{1-}$. Manganese, in the oxidation state of 7+, is similar to chlorine in the same oxidation state in that it forms only cations, and it is only in this condition that manganese has any properties comparable to those of chlorine.

THE ACID-BASE PROPERTIES OF HYDRATED RARE EARTH IONS

The ionic radii of the rare earth elements become progressively shorter in passing from cerium (atomic number 58) to lutecium (atomic number 71) and, in the usual state of oxidation of 3+, there is an increase in acidity of the hydrated ions parallel to the decrease in size. The radii of the ions of the later members of the group are of the same order of magnitude as that of yttrium, 0.93 A., and precipitate with it in the so-called yttrium subgroup, even though yttrium normally appears in the preceding period. In the other states of oxidation, attained by a few of the rare earth elements, the differences are greatly accentuated and rapid means of separating the rare earths are based upon such possibilities of altering the ionic potentials.

[9] EVANS, "An introduction to crystal chemistry," The Macmillan Co., New York City, **1939**, p. 171; STILLWELL, "Crystal chemistry," McGraw-Hill Book Co., Inc., New York City, **1938**, p. 417.

THE ACID PROPERTIES OF STANNIC CHLORIDE

Stannic chloride solutions are acid. This has been interpreted by G. N. Lewis[10] in terms of the electron donor-acceptor theory as due to the tendency of the tin atom to form a complex with a coördination number of six. Thus, according to Lewis, when stannic chloride is dissolved in water, the solution is acidic because it contains *an acid substance*, $SnCl_4$. The acidity arises from the attachment of two molecules of water to the tin kernel, which dissociate to yield $[SnCl_4(OH)_2]^{2-} + 2H^{1+}$, or, by the direct addition of two hydroxyl ions, leaving $2H_3O^{1+}$ ions in excess in the solution. The reaction is undoubtedly not limited to these processes, and the solution probably contains other complexes, such as $(SnCl_6)^{2-}$. The reactions of stannic chloride with water, however, are controlled by the same forces which operate to determine the extent of hydrolysis in other instances, and the equilibria into which the six-coördinated complex enters obey the same rules.

SUMMARY

It is possible that the phenomenon of hydrolysis is one which should not be discussed in elementary courses because of the difficult theoretical treatment required for its adequate elucidation. If it is to be introduced, however, it can profitably be tied up with the concept of the formation of aquo-complexes, and the influences of the ionic potentials. For students in beginning courses in chemistry, it is more beneficial to give an adequate representation of the facts than to insist upon a definite theoretical interpretation. The choice of theory can be left to the judgment of the properly grounded student.

[10] LEWIS, "Acids and bases," *J. Franklin Inst.*, **226**, 293 (1938); *cf.* HILDEBRAND, "Principles of chemistry," *loc. cit.*, pp. 78 and 308; HALL, "Systems of acids and bases," J. CHEM. EDUC., **17**, 124 (1940).

RED GOLD SOLS

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THE method for the preparation of a red gold sol described by D. P. Borovskaya [*Z. Immunitäts.*, **82**, 178–82 (1934); *Chem. Abst.*, **28**, 5485 (1934)] has not received the attention it deserves. High-school teachers and others wishing to demonstrate the preparation of red gold sols find the Zsigmondy method unsatisfactory. We have used Borovskaya's procedure in classes in colloid and physiological chemistry and for gold number studies and found it to be reasonably sensitive and also very easy to prepare.

To 95 cc. of ordinary distilled water, 1 cc. of 1 per cent $AuCl_3$ solution is added and heated to 90–95°C. About $2^1/_2$–5 cc. of 1 per cent sodium citrate are added and the solution is boiled for one and one-half minutes. A light cherry-red sol results. By varying the concentration of citrate and time of boiling, different colored sols may be obtained.

LECTURE DEMONSTRATIONS *in* GENERAL CHEMISTRY[1]

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12. CHEMILUMINESCENCE[2]

We have found that the cold light experiment with "luminol" can be made more spectacular by soaking a wad of absorbent cotton in the luminol solution, pouring some peroxide and potassium ferricyanide on it and wringing this out.

13. THE FLAMMABILITY OF YELLOW PHOSPHORUS

A solution of yellow phosphorus in carbon bisulfide is poured in several places on a newspaper which is quickly folded. An assistant brings it in during the lecture and when it is opened, it bursts into flame. Dr. H. V. Fuller originated the "hot news" newspaper. As a boy in the eighties he saw a conjurer on the stage who had a number of people from the audience open newspapers on the stage after saying a few cabalistic words to them. Years later Dr. Fuller used this stunt in his lectures in Tientsin, China.

14. CHARGE ON FRESHLY FORMED SOOT

To show that freshly formed soot or carbon black has a negative charge, we spread it on white paper and then pass over it a glass rod, charged by rubbing with silk, to which the particles fly like a flock of black crows. We then pass over it an ebony rod which has been charged by rubbing with cat's fur. The particles are repelled by it.

15. NOTE ON OXIDIZING METHANOL TO FORMALDEHYDE, CATALYTICALLY

The experiment of catalytically oxidizing methanol to formaldehyde on platinum wire which is kept red hot by the reaction is not always successful because the directions as given in the Frank and Barlow book, "Mystery Experiments and Problems," do not call attention to the necessity of finding a height above the alcohol at which the methanol-air ratio is near the theoretical two parts of methanol to five parts of air. We find that we can regulate the height of the platinum coil (4-mm. diameter, loops close to about a length of two cm. of 26-gage wire) by the arrangement shown in the diagrams (Figure 11). We also found that it is an advantage to have more holes in the cardboard cover so as to be able to regulate the air by means of stoppers. This is a very old experiment.

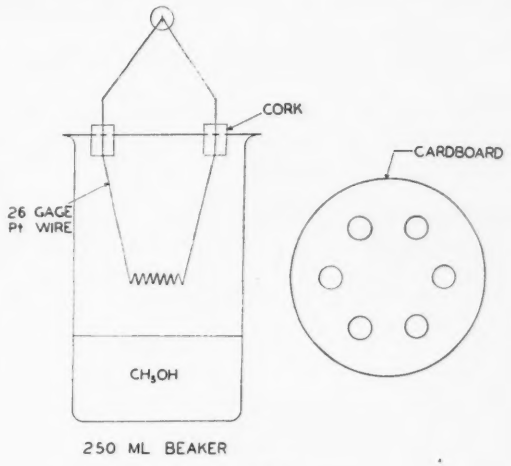

FIGURE 11

16. SOME SHORTER DEMONSTRATIONS[3]

(*a*) *Solubility of Gaseous HCl in H_2O.*—Add conc. H_2SO_4 to conc. HCl in a tall cylinder and, after the evolution of HCl displaces the air, put a plate glass over the mouth and turn upside down in water. If properly done, water rises very fast; I have had it knock the bottom from the cylinder.

(*b*) *Rate of Diffusion.*—Put porcelain boat containing HCl in one end of a glass tube, and one containing NH_4OH in the other. This will not only show rate of diffusion, as described elsewhere, but will also form Liesegang rings in the solid phase.

(*c*) *Colored Flames.*—The sugar-chlorate experiment can be modified as follows: Incorporate Na^+, Ba^{+2}, Sr^{+2}, Ca^{+2}, Cu^{+2}, BO_3^{-3} with portions of the mixture and place in a long trough. Light one end and note the different colored flames.

(*d*) *Rapid Combustion of Wood.*—In the oxygen-glowing splinter experiment melt the chlorate, drop the splinter into the tube (*care!*) and see the fireworks. A pyrex glass test tube will not break.

(*e*) *Magnesium Nitride Formation.*—Burn magnesium turnings in a porcelain dish in air, then add water and cover with a watch glass with red litmus on lower side. The NH_3 gas liberated by hydrolysis of the nitride affects the litmus.

[1] Continued from the October, 1940 issue.

[2] This and the three following demonstrations were contributed by Walter E. Thrun, Head of Department of Chemistry, Valparaiso University.

[3] Contributed by E. E. Chandler, Professor of Chemistry, Occidental College.

17. PHASE CHANGES AND MAGNETIC CHANGES IN IRON (STEEL) IN THE SOLID STATE[4]

This experiment was designed to illustrate qualitatively, and impressively, what happens to a piece of steel when it is heated. The apparatus (Figure 12) is simple and easy to construct, and consists essentially of the following parts: a variable resistance (10 feet of 26-gage nichrome wire), a switch, and the dilatometer proper. High carbon steel wire (18 B & S gage) is used. The grade known as "piano wire" is suitable.

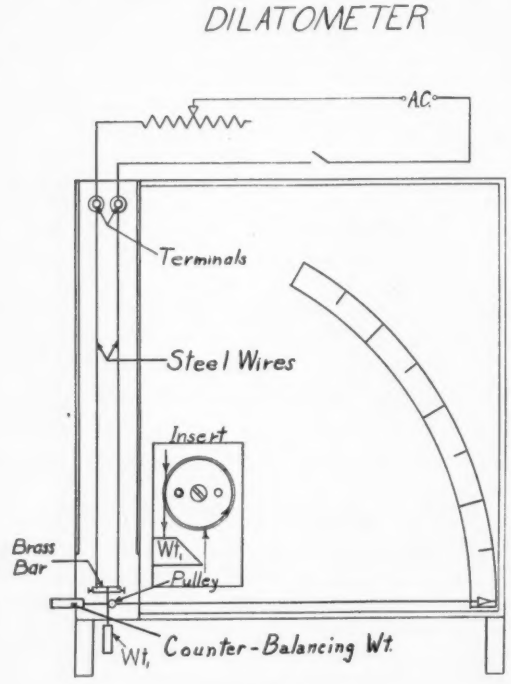

FIGURE 12

About seven feet of wire are used, two lengths of less than four feet each, connected in series as shown. The wires appear to be in parallel, but are actually in series. The terminals project from the board sufficiently so that the wires hang freely. A weight, attached to the brass bar (which connects the bottom ends of the wires) by a string, exerts enough pull to keep the wires hanging straight. By taking a turn of the string about the pulley, a pointer can be actuated as the wires expand or contract, thus magnifying the motion of the wires. In Figure 12, the insert shows details of the pulley, weight and string. The pointer consists of a tube of Duralumin, and it is attached to the pulley, and a counter-weight used, so that the pointer is essentially in balance without reference to the wires or string.

The panel may be made of ply wood, 41′ × 41′, and is supported by a hinged leg (not shown) as an easel. The switch and resistance may be mounted on the back. The scale and its divisions are arbitrary.

At the start of the experiment, the pointer is horizontal, the wires stretched slightly by the weight, Wt_1. When the switch is closed, current from the 110-v. A.C. circuit heats the steel wires as resistance units, and causes them to expand; as they expand the slack is taken up by the weight, thus causing the pointer to move upward. As long as the iron is in the alpha form (body-centered cubic lattice) expansion will continue, but when the phase change, alpha to gamma, takes place, an actual contraction of the steel causes the pointer to reverse its direction of movement. When the gamma iron (face-centered cubic lattice) is formed, expansion will again occur. When the current is cut off, the changes noted will take place in reverse order.

If the wire is tested by a magnet before heating, it will, of course, be attracted; but at the high temperature, the gamma iron will be non-magnetic, as will be found by trial.

The heat absorption at the critical point on heating may be noted by the careful observer, and the "spontaneous glow," at the critical point on cooling (the recalescent point), is easy to see. Both effects are noticed more readily if the experiment is carried out in a darkened room.

Since the time of heating from room temperature to over 900°C. is less than one minute, the phase change on heating will not occur at the temperatures predicted from the iron–iron carbide equilibrium diagram (720°C. approximately), but at some higher temperature, while on cooling the phase change will be at some lower temperature. In an attempt to minimize rapid cooling due to air currents, baffles are built parallel to the wires, and pyrex glass tubes, one inch in diameter, may be placed around the wires, then plugged at both ends with rubber stoppers. Short porcelain tubes over the wires insulate the wires from the rubber stoppers as they enter the tube. However, the device will function without either baffles or glass tubes.

18. EFFECT OF CONCENTRATION UPON REACTION VELOCITY[5]

The double decomposition of sulfuric acid and sodium thiosulfate to produce a finely divided precipitate of sulfur provides an excellent means for demonstrating the effect of concentration upon reaction velocity. A satisfactory vessel in which the reaction may be carried out is a large light-absorption cell. If to the back of such a cell an appropriate legend in black letters is glued (such as WATCH THE LETTERS DISAPPEAR) the legend will be obliterated by the sulfur formed during the course of the reaction. Assuming that a constant amount of sulfur is required for each obliteration, the time required for vanishing of the letters may be considered to be a direct measure of the average reaction velocity. This experiment satisfies

[4] Contributed by George M. Enos, Associate Professor of Metallurgy, University of Cincinnati.

[5] Contributed by H. J. Garber, Assistant Professor of Chemical Engineering, University of Cincinnati.

the fundamental requirement of a good demonstration in that it permits all members of the class to take an active part in the work. The extinction is particularly sharp if the back of the cell is made translucent with paraffin or white paint and is illuminated. Satisfactory results are obtained if 20-cc. portions of $4N$, $2N$, N, and $N/2$ sulfuric acid are added to 200 cc. of $N/25$ sodium thiosulfate solution.

IGNITION *of the* SAFETY MATCH

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THE usual explanation given in inorganic chemistry texts for the ignition of the safety match is the conversion of the red phosphorus on the striking surface to a vapor which then ignites. Some books go so far as to state that the vapor condenses to form white phosphorus which takes fire spontaneously. It is implied that the only function of the oxidizing agent is to keep the antimony trisulfide burning on the head of the match. It is also stated that lead dioxide, potassium chromate, potassium dichromate, or potassium nitrate may be used as the oxidizing agent instead of the potassium chlorate.

Since it is well known that a mixture of red phosphorus and potassium chlorate will react with explosive violence if only little friction is applied, it occurred to the writer that it is the contact of the red phosphorus with the oxidizing agent which causes the primary ignition. In order to test this hypothesis, a number of match sticks were coated with each of the following mixtures:

A—glue, an abrasive (sand or carborundum powder)
B—glue, an abrasive, and $KClO_3$
C—glue, an abrasive, and KNO_3
D—glue, an abrasive, and K_2CrO_4
E—glue, an abrasive, and $K_2Cr_2O_7$
F—glue, an abrasive, and PbO_2
G—glue, an abrasive, and $NaClO_3$

These matches were then struck on a safety match striking surface. Series *A*, *C*, *D*, *E*, and *F* gave no discernible glow or spark even in a dark room. Series *B* and *G* produced sparks visible in daylight.

If phosphorus vapor were formed upon striking the match, it should condense at some cool place on the striking surface to form some white phosphorus which would glow in the dark. Series *A* seems to prove fairly definitely that phosphorus vapor is not formed and that even if it is, it does not ignite. Series *C*, *D*, *E*, and *F* indicate that the oxidizing agents employed were not energetic enough to cause the phosphorus to burn. One is thus led to the conclusion that a chlorate is an essential ingredient in any oxidizing mixture for the safety match. Since sodium chlorate is deliquescent potassium chlorate must be used.[1] The other oxidizing agents are added to prevent too rapid combustion of the head, which would be the case if potassium chlorate were used alone.

The above idea makes it easier to explain why the entire striking surface does not go up in flames when a safety match is struck. The potassium chlorate, being a more powerful oxidizing agent than the atmosphere, causes the oxidation of the phosphorus to proceed at a greater rate than if it were surrounded by air. The increased rate of oxidation will cause the phosphorus to burn at a temperature much lower than its kindling point in air. The rest of the phosphorus on the striking surface, which is not in contact with an oxidizing agent other than air, will not burn at the lower temperature. The Sb_2S_3 in the match head burns because the original phosphorus-$KClO_3$ reaction produces a temperature high enough to kindle the mixture of trisulfide and oxidizing agents in the head.

To confirm this interpretation, the following experiments were performed. A narrow strip of a mixture of red phosphorus, $KClO_3$, and glue was painted on the striking surface of a safety match box. This was dried and then struck with a "match" made of glue and carborundum powder. The red phosphorus-potassium chlorate strip took fire but the rest of the striking surface remained unburnt, showing that the temperature developed was not sufficient to ignite the red phosphorus on the striking surface. A mixture of Sb_2S_3, $KClO_3$, and glue was then spread on a piece of roughened cardboard and allowed to dry. A strip similar to that painted on the safety match striking surface was then put on and dried. On being struck with a carborundum powder "match," the $KClO_3$-phosphorus mixture took fire and ignited the trisulfide-chlorate mixture which in turn ignited the cardboard. To illustrate how low the ignition point of the potassium chlorate-phosphorus mixture is, a sample of this mixture took fire while drying in an oven at 80°C.

The experiments described in this paper bring the author to the conclusion that the usual explanation given for the ignition of the safety match is untenable and that it is erroneous to list oxidizing agents such as K_2CrO_4, PbO_2, etc., as substitutes for $KClO_3$.

[1] The Diamond Match Co. of 30 Church St., New York City, was kind enough to confirm this conclusion.

ELECTROCHEMICAL METHODS *in* ORGANIC CHEMISTRY

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INTRODUCTION

IN TEACHING organic chemistry, the use of electrochemical methods has, for the most part, been somewhat neglected. As a means of preparing a number of organic compounds such methods possess many advantages over purely chemical processes and their use should be emphasized. As a matter of fact, industrial organizations employ electrolytic processes, whenever practical, to avoid losses of material; to gain better control, with simplification of method; and to obtain subsequent purer products. Therefore, it would seem that electro-organic practices not only have a legitimate place in the organic classroom and laboratory but also afford an excellent opportunity to teach the principles involved and to give the student a wider understanding by breaking down the barriers built up by individual subjects or courses. Such integration is in line with the most modern procedures in education and, in planning a beginning organic course, the idea merits consideration. The following plan for incorporating electrochemical methods in the organic course presents first, some important points of the theory involved, and second, some applications which the student may carry out in the laboratory.

THEORETICAL

From the time of Faraday (*1*), who has given us the laws of electrolysis, and of Kolbe (*2*) who, by electrolysis, attempted to isolate free methyl, much fruitful research has been done on both inorganic and organic compounds and their electrochemical preparation.

About the electrodes, many organic compounds react with the products formed by the discharge of ions. These compounds may take up hydrogen or yield oxygen, simultaneously, at the cathode or be oxidized at the anode (*3*). By varying the conditions of electrolysis, the same compound may be made to yield a series of products without the use of different reducing or oxidizing agents which, if used, would be present as impurities. Yields generally show an increased percentage and the products a higher degree of purity and finer crystalline form. Since organic compounds, themselves, are poor conductors, an electrolyte is added and the electrode products combine with the organic compound which is suspended or dissolved in the electrolyte.

Electrolytic preparation depends upon two processes at each of the electrodes. At the cathode (*a*) the primary process involves discharge of hydrogen ions,

$$H^+ + \epsilon = H$$

and (*b*) the interaction of the cathodic depolarizer and nascent hydrogen. At the anode (*a*) the primary process involves discharge of hydroxyl ions,

$$2OH^- = H_2O + O + 2\epsilon$$

and (*b*) the interaction of the anodic depolarizer and nascent oxygen. When halides are used, the anodic process liberates nascent halogen which reacts as quickly as produced.

The nature of the reaction is influenced and determined by three factors. They are: (1) electrode potential, (2) velocity of reaction at the electrodes, and (3) use of catalysts.

The electrode potential may be shown to be proportional to the concentration of active hydrogen or oxygen. The magnitude of the electrode potential is a measure of its reducing (*4*) or oxidizing power, being greater for higher potentials. These potentials may be regulated by controlling the current density, the temperature, the kind of electrode materials and the conditions of electrolysis. This regulation results in various intermediate products, depending upon the amount of reaction energy necessary, and those substances which react at a potential above that required for liberation of nascent hydrogen or oxygen are not acted upon to any great extent. Materials of high hydrogen overvoltage or high oxygen overvoltage permit high electrode potentials without liberation of gaseous hydrogen or oxygen and are necessary in reactions requiring greater amounts of energy. Electrode materials differ among themselves with respect to overvoltage and frequently determine the resulting products of an electrolytic process.

If the velocities of the primary reactions (*a*), above, are faster than those of (*b*), above, the concentrations of nascent hydrogen and oxygen increase, electrode potentials rise, and the gases are liberated. Any factor, then, which makes for a lower current density is desirable. This condition may be accomplished by employing either a large cathode surface in reducing reactions or a large anode surface in oxidation reactions, and by providing for an increase in concentration of depolarizing material around the appropriate electrode. Stirring is, of course, advantageous.

Catalysts are used to accelerate slow reactions between active hydrogen, or active oxygen, and reacting materials (*5*, *6*, *7*). The catalyst should be one which, itself, is capable of being either reduced or oxidized, acting as a hydrogen or oxygen carrier, and being regenerated at the corresponding electrode for further duty. The electrode potential, on the other hand, need not be

higher than is necessary for the reduction or oxidation of the catalyst. It must be borne in mind that the electrode surface should be such as to allow the reaction to proceed readily and with a high velocity. This is attained, generally, by employing rough electrodes in preference to smooth surfaces. Catalytic action of the electrode material often plays an important role in the electrolytic process (*8*).

In carrying out electrochemical reactions, it must be remembered that cathodic reduction products may be oxidized at the anode and, also, that anodic oxidation substances may be reduced at the cathode. To prevent this, in the former case, the anode is frequently separated from the cathode by a diaphragm, or porous cup; or a small anode surface is employed for the purpose of attaining a high current density. Many times it is desirable to use an anode material of low oxygen overvoltage. The same kind of precautions need to be taken to prevent reduction of anodic oxidation products at the cathode (*9*).

The number of electrode materials which may be employed in electrolytic oxidations is rather limited since oxide layers coat the electrodes. In acid or alkaline media, carbon and platinum are usually employed while iron and nickel are best suited to alkaline solutions. The presence of traces of foreign metals in the electrode materials lowers the overvoltage considerably.

Aside from purely oxidation and reduction reactions, the electrolysis of many organic compounds is possible owing to the large number of organic anions. The cations of organic electrolytes usually do not take part in any cathodic reaction except, possibly, in a relatively few cases of organic bases. With concentrated solutions of aliphatic monobasic acids, or their salts, union takes place between discharged anions with subsequent splitting off of carbon dioxide from the newly synthesized molecule. In these types of reactions higher current densities are necessary. As a rule these reactions may be classified as follows:

$$2C_nH_{2n+1}COO^- = C_{2n}H_{4n+2} + 2CO_2 + 2\epsilon \quad (1)$$

$$2C_nH_{2n+1}COO^- = C_nH_{2n} + C_nH_{2n+1}COOH + CO_2 + 2\epsilon \quad (2)$$

$$2C_nH_{2n+1}COO^- = C_nH_{2n+1}COOC_nH_{2n+1} + CO_2 + 2\epsilon \quad (3)$$

By the use of suitable coulometers (*10*), the student may determine the current efficiency, which is an important factor in many electrochemical processes. He learns, also, to understand the occurrence of side reactions and how yields are, thereby, diminished.

Tables suggesting some electrochemical reactions, which may be carried out in the organic laboratory, together with detailed references, follow.

SOME EXERCISES INVOLVING ELECTROCHEMICAL APPLICATIONS

TABLE 1

REDUCTIONS

Preparation	*Catholyte*	*Anolyte*	*Cathode*	*Anode*	*Temp., °C.*	*Yield, %*	*C. E.**
p-Aminophenol (*11*)	20 g. nitrobenzene; 150 g. conc. sulfuric acid; few drops water	Conc. sulfuric acid; few cc. water in porous cup	Pt gauze D_c 4–6†	Pt sheet	60–90	20–50	—
p-Aminophenol (*12*)	20 g. nitrobenzene in 91% sulfuric acid solution	82% sulfuric acid solution in porous cup	Pt gauze D_c 3–4	Pt sheet	30	40–50	25
p-Aminophenol (*13*)	20 g. *p*-nitrophenol; 6 g. sodium hydroxide in 300 cc. water	Sodium carbonate solution in porous cup	Pt gauze D_c 10	Pt sheet	—	80	90
o-Aminophenol (*14*)	20 g. *o*-nitrophenol; 6 g. sodium hydroxide in 300 cc. water	Sodium carbonate solution in porous cup	Pt gauze D_c 10	Pt sheet	—	60	90
Azoxybenzene (*15*)	30 g. nitrobenzene; 240 g. 2.5% sodium hydroxide solution in porous cup	Sodium sulfate solution, acidified with sulfuric acid	Ni gauze D_c 5–7	Pb or Pt sheet	—	60	—
Azobenzene (*16*)	20 g. nitrobenzene; 5 g. crystallized sodium acetate; 200 cc. 70% alcohol in porous cup	Sodium carbonate cold saturated solution	Ni gauze D_c 6–9	Pb or Pt sheet	B. P.	90	80
Hydrazobenzene (*16*) (benzidine)	Same as azobenzene		D_c 1–3	Same as azobenzene		90	80
Aniline (*17*)	20 g. nitrobenzene; 150 cc. alcohol; 125 cc. sulfuric acid, sp. gr. 1.2	Sulfuric acid, sp. gr., 1.1, in porous cup	Pb perforated cylinder D_c 3–6	Pb sheet	B. P.	86–87	—
o-Toluidine (*17*)	Same as aniline					75–85	—
2-Hydroxy-5-aminobenzenesulphonic acid (*18*)	40 g. nitrobenzene; 150 g. sulfuric acid (fuming), sp. gr. 1.88	Conc. sulfuric acid in porous cup	Pt gauze D_c 2–6	Pt sheet	80–120	40	80
Benzhydrol (*19*)	30 g. benzophenone; 6 g. crystallized sodium acetate; 500 cc. 96% alcohol; 100 cc. water	Sodium carbonate cold saturated solution in porous cup	Pb perforated cylinder D_c 0.4–0.8	Pb plate	Heated during experiment	90	80–90
Isopropyl alcohol and pinacone (*20*)	30 g. acetone; 6 g. crystallized sodium acetate; 500 cc. 96% alcohol; 100 cc. water	Sodium carbonate cold saturated solution in porous cup	Pb vessel D_c 4	Pb	Kept cool	—	—
p-Phenylenediamine (*21*)	20 g. *p*-nitraniline; 5 g. crystallized sodium acetate; 200 cc. 70% alcohol in porous cup	Sodium carbonate solution	Ni gauze D_c 2	Pb or Pt sheet	—	80	90
Stearic acid (*22*)	20 g. oleic acid; 300 cc. alcohol; 2 cc. 20% sulfuric acid	5% sulfuric acid in clay cylinder	Ni gauze D_c 1.5	C	—	12.4‡	10‡
Piperidine (*23*)	20 g. pyridine; 200 cc. 10% sulfuric acid	No diaphragm	Pb sheet D_c 10–12	Pb (small)	50–60	—	—

* C. E.—current efficiency.
† D_c—cathode current density, amperes per square decimeter.
‡ After 1 ampere hour.

TABLE 2

OXIDATIONS

Preparation	*Catholyte*	*Anolyte*	*Cathode*	*Anode*	*Temp., °C.*	*Yield, %*	*C. E.*
p-Nitrobenzyl alcohol (*24*)	Sulfuric acid, sp. gr. 1.6–1.7	15 g. *p*-nitrotoluene; 80 g. glacial acetic acid; 15 g. conc. sulfuric acid; 7 g. water in porous cup	Pb	Pt foil or gauze (large) D_a 1.5*	Heated by boiling water bath	40	30
Benzaldehyde (*25*)	No diaphragm	59 g. toluene; 200 cc. 10% sulfuric acid; 250–300 cc. acetone	Pt spiral	Pt foil D_a 1.5–2	Below 20	10	—
Iodoform (*26*)	Same as anolyte; diaphragm of parchment paper	20 g. anhydrous sodium carbonate; 20 g. potassium iodide; 50 cc. 96% alcohol; 200 cc. water	Pt foil (small) in parchment paper	Pt gauze (large) D_a 1–3	50–70, CO_2 passed into solution	—	80
Bromoform (*27*)	Same as anolyte; diaphragm of parchment paper	60 g. potassium bromide; 0.3 g. potassium chromate; 150 cc. water; 20 cc. acetone	Pt spiral in parchment paper	Pt sheet D_a 3	18–20, CO_2 passed into solution	60	—
Chloroform (*28*)	Same as anolyte; diaphragm of parchment paper	120 g. sodium chloride; 10 g. sodium carbonate; 500 cc. water; 30 g. sodium bicarbonate	Pt spiral in parchment paper	Pt foil D_a 55	Below 30	20–30	—
Methyl alcohol (*29*)	No diaphragm	225 g. potassium acetate; 52 g. potassium carbonate; 55 g. potassium bicarbonate; water to make 1 liter	Pb	Pt D_a 20–25	25–30	50–60	—
Anthraquinone (*30*)	No diaphragm	20 g. anthracene; 900 cc. water; 100 cc. conc. sulfuric acid; 1.5 g. ceric sulfate in Pb vessel	Pb paddle	Pb vessel D_a 1–2	75–90	—	80

* D_a—anode current density, amperes per square decimeter.

TABLE 3

COUPLING REACTION

Preparation	*Catholyte*	*Anolyte*	*Cathode*	*Anode*	*Temp., °C.*	*Yield, %*	*C. E.*
β-Naphtholazobenzene-monosulfate (*31*)	10% sodium hydroxide solution in 2 porous cups	19.5 g. sodium salt of sulfanilic acid; 14.4 g. β-naphthol; 6.9 g. *pure* sodium nitrite; 150 cc. water	Ni or Pt wire	Pt sheet D_a 8–12	Cooled by ice bath	—	—

TABLE 4

ANION REACTIONS

Preparation	*Catholyte*	*Anolyte*	*Cathode*	*Anode*	*Temp., °C.*	*Yield, %*	*C. E.*
Ethane (*32*)	Saturated sodium acetate solution in cold; few cc. acetic acid	Same as catholyte solution in porous cup	Ni or Cu gauze around porous cup	Pt spiral or sheet D_a 50–100	Below 20	—	90
Ethylene (*33*)	30 g. sodium propionate; 25 g. propionic acid; 80 g. water	Same as catholyte solution in porous cup (bromine added converts ethylene to the dibromide)	Pt foil	Pt wire or spiral D_a 100	Up to 40	—	36–54
Trichloromethyl ester of trichloroacetic acid (*34*)	Sodium chloride solution	30 g. trichloroacetic acid; 100 g. water saturated with equal weights anhydrous sodium carbonate and zinc carbonate in porous cup	Pt or Pb cylinder around porous cup	Pt sheet D_a 40–50	Kept cool	10–30	—
Diethyl ester of adipic acid (*35*)	No diaphragm	1.5 parts potassium ethyl ester of succinic acid to 1 part water	Pt sheet	Pt spiral D_a 50–100	Kept cool	30–35	—

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DISTINGUISHING INDIVIDUAL QUANTITATIVE FILTER PAPERS

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PACKAGES of quantitative filter papers bear distinguishing marks, either colored bands or numbers, indicating the texture of the paper enclosed, but students in elementary classes need only a few circles and to save them unnecessary expense the packages are broken in the stockroom. This separates the paper from the marks and introduces several possibilities of error. Careless stockroom clerks, not realizing the importance of the markings, may hand out the wrong kind, or return surplus circles to the wrong package. The student may ask for the wrong type, and the circles given him do not by their appearance awaken a sense of error. The student may obtain two or more kinds of paper at one time and unintentionally mix them before use. The place for the distinguishing mark is on the paper itself and it can be easily placed there if a color code is used. Aqueous solutions of organic dyes can be streaked along the edge of the package, thus marking every circle. When folding, the corner of the folded-back section can be located at this spot and torn off. Even when not thus removed the dye adds no appreciable weight to the ash of the paper. Two thousand spots were made by two milligrams of dye dissolved in one milliliter of water. Thus, there is an average of one microgram per spot and loss of dye by leaching or its decrease in weight on ashing decreases this. Stability of color to laboratory fumes is important and the dyes tested were subjected to the fumes of boiling 6 *N* NH_4OH and boiling concentrated HCl. The dyes recommended are (1) Water Blue of Heller and Merz for the close-textured paper used for fine-grained precipitates, (2) Nigrosine CPP of Heller and Merz for the loose textured paper used for gelatinous precipitates, (3) Erie Fast Scarlet 4 BAP of National Aniline Company for the intermediate texture now distinguished by a white band, and (4) Auramine OP of National Aniline Company for the fat-free white band paper. Within a few weeks of starting to use this system the author found two students folding the wrong kind of paper for precipitates standing ready in the beakers. Without identification marks on the circles this error could not have been noticed.

SOME INTERESTING EXAMPLES OF RHYTHMIC PRECIPITATION

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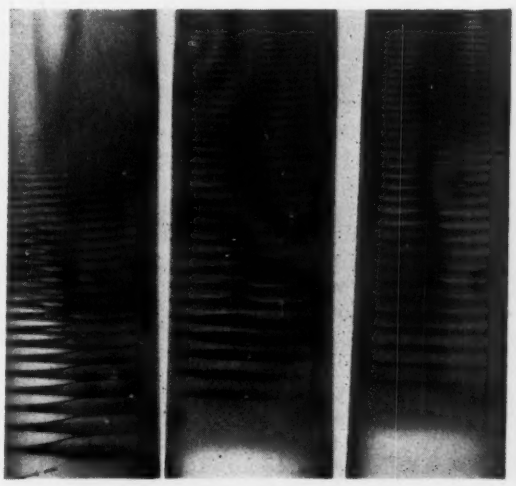
ALTHOUGH Ostwald[1] has already reported a spiral arrangement in the rhythmic precipitation of cobaltous hydroxide in gelatin, the examples illustrated seemed sufficiently unusual to merit recording. Each of the samples, of which only the banded structures are shown, was prepared as follows: To 30 ml. of a hot ten per cent gelatin solution in a 17-cm. pyrex test tube were added 5 ml. of a $M/10$ cobaltous nitrate solution. After setting, the gel was then covered with 10 ml. of a $M/5$ ammonium hydroxide solution. The tubes were stoppered and allowed to stand in the light of the laboratory, the first one being photographed after eight days and the other two after five days. The green bands of cobaltous hydroxide were joined along one side of the tube in each instance, but this linking tendency disappeared as the bands became more widely separated. While the structures illustrated are not true spirals, they represent a rather interesting type of Liesegang phenomenon.

[1] OSTWALD, "Zur Theorie der Liesegang'schen Ringe," *Kolloid-Z.* (Zsigmondy Festschrift), **36**, 390 (1925).



A LABORATORY EXPERIMENT *in* GENERAL CHEMISTRY

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A NEW type of experiment in general chemistry is here described which deals qualitatively with certain prominent chemical reactions involving compounds of the halogen, sulfur, and nitrogen families. There is a need for such an experiment because (1) the principles of oxidation and reduction are first systematically applied at this point, and (2) because of the wide field which is covered in a limited time. Because of the latter point the experiment is made qualitative.

The experiment consists of two parts. In the first part qualitative observations are made on color changes, evolution of gases, and the formation of precipitates when compounds of these families react. In the second part each student is given an unknown to be identified without the use of any chemicals other than those present in the unknown. Nine bottles, each containing a colorless water solution of a pure chemical, are issued to each student. The bottles are labeled with numbers from 1 to 9, and along with the set is given a list of the nine chemicals contained in the bottles but the order of arrangement is not given. The student's problem is to mix portions of the contents of the various bottles, observing the results, and to deduce from these the identity of the chemicals.

The chemicals were chosen from the list of eighteen given at the top of Table 1. The points that were kept in mind when selecting them were to have (*a*) common anions, (*b*) salts that hydrolyze, (*c*) oxidizing and reducing agents, and (*d*) one or more precipitants. A list of twenty-one tested unknowns is given in Table 1. A cross in the column headed by a chemical means that this particular chemical is included in the set. On the basis of experience in the laboratory the sets are arranged in the approximate order of their difficulty, the first five being easiest and the last five most difficult. Number 22 will be referred to later.

TABLE 1

	$AgNO_3$ 0.1 *M*	*HCl* 6 *M*	H_2SO_4 9 *M*	HNO_3 6 *M*	Na_2SO_3 0.5 *M*	*NaBr* 1 *M*	NH_4Cl 3 *M*	$KClO_3$ 0.5 *M*	$NaNO_2$ 1 *M*	*NaS* 0.5 *M*	*KI* 0.3 *M*	KIO_3 0.2 *M*	Na_2SO_4 0.3 *M*	*NaOH* 6 *M*	Na_2SiO_3 0.2 *M*	$BaCl_2$ 0.2 *M*	*NaCl*-*NaClO* 0.6 *M* NaOH satd. with Cl_2	H_2O
1	x	x			x	x	x	x	x				x			x		
2	x		x		x			x	x	x	x					x		x
3	x					x	x		x	x	x		x	x		x		
4	x				x	x	x		x		x			x		x		x
5	x	x	x	x	x		x					x				x		x
6	x			x	x		x			x	x	x					x	x
7	x	x			x	x	x	x	x	x		x						
8			x		x		x	x	x			x	x			x		x
9			x			x	x	x		x	x			x		x		x
10			x		x			x			x		x		x	x	x	x
11	x	x			x	x	x		x	x		x					x	
12			x		x		x	x		x	x		x		x	x		
13	x					x	x	x		x		x	x	x		x		
14		x		x			x	x	x	x				x		x		x
15		x				x	x			x	x	x				x	x	x
16	x	x			x	x	x		x		x		x		x			
17		x			x		x		x	x	x	x	x				x	
18		x				x	x	x	x	x	x	x	x					
19	x	x			x	x	x		x	x		x					x	
20		x				x		x		x	x	x				x	x	x
21			x	x	x	x	x		x		x			x	x		x	
22	x	x		x			x		x	x		x		x		x		

A description of the experiment can best be accomplished by working out an example in detail. Data for set number nine of Table 1 are shown in Table 2. The results obtained when the chemicals are mixed in pairs are given in the lower left-hand portion of the table and in the upper right the results when the chemicals are mixed in sets of three, *e. g.*, when a few drops of bottle No. 3 are mixed with a few drops of bottle No. 5 a white precipitate results. From Table 1 the chemicals present are H_2SO_4, NaBr, NH_4Cl, $KClO_3$, Na_2S, KI, NaOH, $BaCl_2$, H_2O.

Since 8 and 6 give NH_3 and 8 and 5 give H_2S either 8 or 6 must be NH_4Cl and either 8 or 5 must be Na_2S. On mixing 7 and 6 an evolution of heat takes place, and hence must be the result of mixing an acid and a base; from the list it follows that 7 must be either H_2SO_4 or NaOH and 6 must be either NaOH or H_2SO_4. If 6 were H_2SO_4 then, from the preceding statement, 8 must be NH_4Cl; but H_2SO_4 and NH_4Cl do not react to give NH_3, hence 6 cannot be H_2SO_4; it follows that 6 must be NaOH. Also 8 must be NH_4Cl; 5, Na_2S; and 7, H_2SO_4. These conclusions are partially confirmed since 7 and 5 give a white precipitate (free sulfur) and H_2S, which is to be expected when H_2SO_4 and Na_2S are mixed. Since 7 is H_2SO_4, we expect a white precipitate of $BaSO_4$ when 7 is mixed with $BaCl_2$. On examining the table we find that 7 and 3 give a white precipitate, hence 3 must be $BaCl_2$. Na_2S solutions invariably contain $SO_4^=$ (due to oxidation in air) and hence we expect a white precipitate when 5 and 3 are mixed. From the table we see that this is observed. On mixing 6 and 3 we get a cloudy solution due to precipitation of $Ba(OH)_2$; the precipitate appears only when an excess of NaOH is added. We obtain H_2S on mixing 8 and 5 due to the hydrolysis of NH_4Cl and Na_2S, one giving an acid and the other a basic solution. If a small quantity of NH_4Cl is added to a large quantity of Na_2S, the odor of ammonia is perceptible. In the example given, a knowledge of the hydrolysis of these salts is not necessary.

There remain to be identified Nos. 1, 2, 4, and 9 which may be either $KClO_3$, H_2O, NaBr, or KI. Of these chemicals, $KClO_3$ acts as an oxidizing agent in acid solution; NaBr and KI are oxidized by $KClO_3$ in acid solution.[1] In the upper right portion of Table 2 are shown the results of adding H_2SO_4 (No. 7) to all possible combinations of these four chemicals taken two at a time. 1 + 7 + 4 gives I_2, and 1 + 7 + 9 gives Br_2, hence 1 must be $KClO_3$, 4 must be KI and 9 must be NaBr. The only remaining possibility for H_2O is 2. The chemicals are then identified as follows:

No. of bottle	*Chemical*	*No. of bottle*	*Chemical*
1	$KClO_3$	6	NaOH
2	H_2O	7	H_2SO_4
3	$BaCl_2$	8	NH_4Cl
4	KI	9	NaBr
5	Na_2S		

This example is based upon data collected in the laboratory on an actual unknown. The identification presented here proved to be correct. The experiment has been tried several times with groups of students ranging in number from fifty to a hundred and sixty. From this experience it became evident that not all of the unknowns are of equal difficulty. On the basis of opinions submitted by various members of the staff, the unknowns are grouped into three classes as stated previously. Number 22 is an unknown so devised that the student determines not only what the arrangement of chemicals is but also what nine of the eighteen are present.

The experiment requires three two-hour laboratory periods, the first of which is devoted to a preliminary exercise on some properties of the eighteen chemicals (first part). The list of chemicals which a sample contains is given out to the student the period before the unknown is worked and each student is required to present a plan for identification. In order that the student may clearly understand what is required, a demonstration is given by the laboratory instructor in which an unknown is worked. The demonstration requires about forty minutes. A written report is turned in by each student, with chemical equations, in which the steps in identification are presented. All eighteen chemicals are placed in the laboratory in stock bottles so that students may run comparison experiments at any time. In general the number incorrectly identified may be as high as five. Half of an average class will correctly identify all of the chemicals in their unknown.

The unknowns are issued in one-ounce square bottles with rubber stoppers. The stoppers must be free from sulfur in order to prevent sulfur from disssolving in Na_2S and NaOH. Most satisfactory results are obtained by using amber-colored bottles, to prevent reduction of $AgNO_3$, although clear glass is satisfactory if $AgNO_3$ solution is prepared just before use. It is necessary to prepare Na_2S and Na_2SO_3 solutions just prior to use in order to prevent oxidation by air.

The students have exhibited unusual interest in the experiment, which, in the opinion of the authors, affords useful training both in making careful qualitative observations and in making logical deductions based on these observations. It is the authors' experience that students who do not accurately record their observations have very little success in identifying the unknowns.

It is immediately evident that the principle involved can be readily applied to other chemicals than those listed. This particular application is given in detail only because the unknowns have been previously tested.

The authors are obligated to many members of the staff for helpful suggestions.

[1] There is no danger of explosion with a dilute solution of $KClO_3$.

TABLE 2

	1	2	3	4	5	6	7	8	9
1									
2	No reaction								
3	No reaction	No reaction							
4	No reaction	No reaction	No reaction						
5	No reaction	No reaction	White ppt.	No reaction					
6	No reaction	No reaction	Cloudy	No reaction	No reaction				
7	No reaction	No reaction	White ppt.	No reaction	White ppt. + odor of H_2S	Heat evolved			
8	No reaction	No reaction	No reaction	No reaction	Odor of H_2S	Odor of NH_3	No reaction		
9	No reaction	No reaction	No reaction	No reaction	No reaction	No reaction	No reaction	No reaction	

(*a*) 1 + 7 + 2 → No reaction
(*b*) 1 + 7 + 4 → I_2
(*c*) 1 + 7 + 9 → Br_2
(*d*) 2 + 4 + 7 → No reaction
(*e*) 9 + 7 + 2 → No reaction
(*f*) I_2 [from (*b*)] + 7 + 1 (excess) → colorless solution

FREEZING POINT EXPERIMENTS *for* UNDERGRADUATES

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WITH the rapid development of physical chemistry, the teacher of this subject finds himself in somewhat of a quandary as regards the objectives of his laboratory work and how they may best be met. He may wonder whether he serves best when his experiments are selected and equipped to emphasize the high degree of accuracy that is so essential to original contribution in the field. Or again, he may question whether his mission is better fulfilled with a larger group of experiments which aim to clarify and supplement the theoretical aspects of a more representative portion of the subject.

Perhaps both of these extremes represent desirable objectives, but each has its practical disadvantages. If stress is placed upon accuracy, the simple principle of the experiment may well be obscured[1] by highly developed apparatus, temperature control, and indirect devices for measurement. In any case, such experimentation is inordinately time-consuming and may lead to neglect of equally important phases of the subject. It is likewise unfortunate if a large group of only semiquantitative experiments conveys an erroneous impression of the mathematical approach to the subject and the accuracy necessary for original work at the present time. Union of these objectives in a single course is open to criticism from many angles, and perhaps the ultimate solution will be found in a general course to illustrate the simple principles, followed by one in which training in refined measurement is paramount.

That we are in a state of doubt is well illustrated in the usual manual, where we find experiments developed to varying extents depending upon such factors, perhaps, as the length of the laboratory period, the probable institutional budget, the history of the experiment and even that of the author of the text. Freezing-point determinations constitute a particularly suggestive case in point. The earliest equipment was undoubtedly of the most simple type. Then came the extensive work of Beckmann and the widespread use of the technic which he developed. And now, for the most part, significant measurements can be made only with extremely rapid mechanical stirring and multiple-junction thermocouples.

The usual laboratory text indicates that undergraduate experimentation has followed the procession through the second stage, with here and there a compromise by introduction of difficultly purified chemicals because of advantages such as high molal depression. Although still extensively used, and adequate for many purposes, there is question as to the value of the use of the Beckmann thermometer by an undergraduate, particularly in view of the time required for the "setting," so essential if its use is to be of any personal significance to the student. Since it no longer represents the method of highest accuracy attainable in the field, perhaps there is advantage in turning again to the simple principle.

Upon examination of a large group of recent texts, it is found that almost all undergraduate laboratory manuals in physical chemistry include freezing point measurements using the Beckmann thermometer. There is a marked tendency to use benzene solutions entirely, while if water solutions are used the experiments rather uniformly call for a single study of urea as solute. Thus there is presented to the teacher a serious difficulty when his classes are large. In addition to the time element, the expense and fragile nature of the Beckmann thermometer render it unsuitable for such groups. The hygroscopic nature of organic solvents necessitates immediate, individual purification or, under ordinary conditions, renders the accuracy of the thermal measurement inconsistent.

The writers have found it practicable to use aqueous solutions throughout the required experiments covering the usual types. Thus, sugar serves successfully as the solute in molecular weight determination, resorcinol for studies of association and many common pure salts may be used for the study of electrolytic solutions. For all of these experiments a simple, rugged, and inexpensive 0° to −5° thermometer is quite satisfactory.

Description of these experiments is given below. Their simple nature enables each student to perform more measurements than is possible with the usual limitations of time and apparatus. More rapid workers may be allowed to work with non-aqueous solutions and with the Beckmann thermometer.

To judge the success of these experiments, statistical analysis was applied to the results obtained by a large group of about equal numbers of premedical, chemistry, and chemical engineering students. The results were calculated directly from the experimental data handed in at the end of each laboratory period. Comparison with the student calculations appearing in their final written reports revealed but few lapses of integrity or failures of comprehension. The findings of the three groups were about equal, and the statistical analysis of the whole group is reported in the description of each experiment.

[1] MILLER AND LUCASSE, J. CHEM. EDUC., 13, 581–5 (Dec., 1936).

THE GENERAL EXPERIMENTAL PROCEDURE

The ordinary student freezing point apparatus[2] was used and students worked most efficiently in groups of two, one performing the weighings, the other setting up the apparatus, while both worked together in making the measurements.

The thermometers[3] were one-fourth of an inch in diameter and thirteen inches in length including a one and one-half inch bulb. The graduations started one and one-half inches from the top and read downward from 0°, being marked at each even-numbered tenth. The smallest divisions, representing two one-hundredths of a degree, were slightly more than one-fiftieth of an inch apart, the markings covering a length of five and one-half inches.

Using a seven-inch pyrex test tube as the freezing point tube, the stopper carrying the thermometer and stirrer slightly obscured the lowest scale divisions which in practice were seldom used. The liquid covering but a little more than the bulb of the thermometer, obviously, there resulted a maximum exposure of stem. However, in successive determinations the stem error was thus rendered practically constant and disappeared in the difference in the readings. A warning was necessary to the effect that the stem must not be touched by hand, it being found that an error as high as one-hundredth of a degree can result in this way.

With the aid of a hand lens, temperatures were estimated to 0.005°, and each group calibrated the 0° value by several determinations with pure water. Since the serial number of the thermometer was recorded by each group, those thermometers causing consistent trouble were easily eliminated. In general, the precision of measurement was better than ±0.01° as shown by the agreement of the student calibrations and a more extensive calibration of several of the thermometers at different points. Similar 5° to 0° thermometers served with equal success in work with benzene solutions.

Three separate determinations were required for the freezing point of each solution studied, and the supercooling was recorded for each determination so that the correction could be made for the change in the amount of solvent due to supercooling by means of the equation

$$W' = W(1 - s/80)$$

in which W' is the corrected amount of solvent, W the amount of water weighed out for the measurement and s the number of degrees of supercooling. Supercooling was kept low by adjustment of the cooling bath since correction was not made for the fact that the true freezing point is not obtained after supercooling takes place.

Although, like the stem correction, the supercooling error acts to produce high values of the measured depression in the freezing point, the error is not serious in undergraduate work as shown by the results given. On the other hand, use of supercooling has the advantage of marking sharply the incidence of freezing and makes the entire measurement more rapid. The addition of solid solvent followed by analysis of the solution at equilibrium introduces an inordinate amount of additional work to obtain a degree of precision often more imaginary than actual with undergraduates.

Since the freezing points were read to three significant figures, the weighings of the solute and solvent were made to four figures only.

THE MOLECULAR WEIGHT OF CANE SUGAR

As might be expected in view of the possible accuracy, ordinary commercial refined sugar and Merck's Reagent Sucrose gave equally satisfactory results in these experiments. However, the latter is in very convenient form and furthermore seemed to impress the students as to the need for purity of chemicals and for general manipulative care. In either case this material is ideal for such studies due to purity, stability and high molecular weight. Two concentrations were studied, of about 1.5 and 3.5 grams in twenty-five grams of water. In case the solution was prepared too late in the period to allow measurement, standing in stoppered flasks caused no deterioration.

The equation used for calculation of the molecular weight, M, was

$$M = \frac{1855\ g}{W'\ \Delta T}$$

where g is the weight of sugar, W' the corrected weight of solvent and ΔT the observed depression. The arithmetic mean of the results of two hundred ninety-eight experiments was 331 with a mean error of ±0.8 and the mean error of each experiment amounted to ±4.4 per cent. Of these, about two-thirds, or one hundred ninety-three experiments met the usual requirement that each value be within five per cent of the true molecular weight, 342. The arithmetic mean of these accepted results was 337 with a mean error of ±0.6 and the mean error of each determination was ±2.4 per cent. The definitely low value of the mean (337 is 1.5 per cent low) must be ascribed to the supercooling effect mentioned above.

THE ASSOCIATION OF RESORCINOL

A study of solutions of resorcinol in water was designed to replace the usual experiment with benzoic acid in benzene. It is based on the work of Bourion and Tuttle[4] who studied the molecular association, showing that the following equilibrium exists in the range 0.8 to 3 molal in aqueous solution

$$3\ C_6H_4(OH)_2 = [C_6H_4(OH)_2]_3$$

The degree of association[5], x, is given by the equation:

[2] *Cf.*, FINDLAY, "Practical physical chemistry," 5th ed., Longmans, Green and Company, New York City, 1933, pp. 119–20.

[3] Such thermometers may be ordered to specification. Those used in the present experiments were obtained from the Precision Thermometer and Instrument Company, 1434 Brandywine Street, Philadelphia, Pennsylvania, and in lots of one dozen cost about $3.20 each.

[4] BOURION AND TUTTLE, *J. chim. phys.*, **25**, 485–96 (1928).

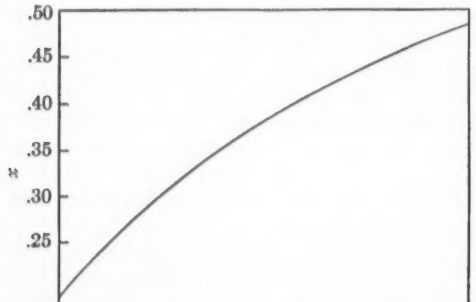
[5] *Cf.*, FINDLAY, *loc. cit.*, p. 127.

$$x = 3/2\left[\frac{(\Delta T)_i - (\Delta T)_0}{(\Delta T)_i}\right]$$

where $(\Delta T)_0$ is the observed depression and $(\Delta T)_i$ is the value that would be expected for an unassociated solute at the same concentration. Figure 1 shows the variation of x with concentration. The curve was constructed from values calculated from the data of Bourion and Tuttle and at the following rounded molal concentrations, leads to the corresponding values of x.

TABLE 1

m	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2
x	0.242	0.288	0.328	0.363	0.394	0.422	0.445	0.467



THE DEGREE OF ASSOCIATION OF RESORCINOL IN WATER AS A FUNCTION OF THE CONCENTRATION

The students were directed to study two concentrations, of 2.5 and five grams of resorcinol (Merck's U.S.P. recrystallized) in twenty-five grams of water. These concentrations are about 1 and 2 molal and should give values of x in the neighborhood of 0.3 and 0.45, respectively. The solutions were measured as soon as prepared, since standing results in noticeable oxidation of the resorcinol.

In judging the accuracy of the results, the students could calculate the molarities with the aid of density data and evaluate the equilibrium constant, the value of which is about 0.31 and constant over the range studied. In actual practice, however, it was considered that the direction of change of the degree of association with concentration was sufficient for elementary student work.

To judge the usefulness of the experiment, statistical analysis was made of the results in the following manner. The per cent deviation of each determination from the true value was determined graphically from a figure similar to the one above. The arithmetic mean of these per cent deviations for two hundred fifty-two experiments was −0.29 per cent, again showing the effect of supercooling. The average per cent error of each determination was 8.29 per cent and the mean per cent error of each determination was 10.826 per cent. These high errors result from the subtraction of $(\Delta T)_0$ from $(\Delta T)_i$ in the calculation of x. That the results are satisfactory for illustration of the change in the degree of association is shown by the fact that in almost every case the variation of x with the concentration was in the correct direction.

THE OSMOTIC COEFFICIENTS OF STRONG ELECTROLYTES

The use of the osmotic coefficient, g, in the interpretation of the colligative behavior of solutions of strong electrolytes has certain advantages. Understanding of the term is easier than that of the activity coefficient and its use in dealing with the colligative properties is adequate.[6]

Since the variance of the osmotic coefficient with change in concentration is of greatest interest to the student, the most striking results should be expected in the use of salts of higher valence type. Thus, it was found that magnesium sulfate is more satisfactory for these experiments than potassium chloride. To compare these, concentrations of 0.4 and 0.8 grams of potassium chloride in twenty-five grams of water (about 0.25 and 0.5 molal) and 0.3 and 3.0 grams of $MgSO_4 \cdot 7H_2O$ in twenty-five grams of water (about 0.05 and 0.5 molal) were studied. The change in g for potassium chloride over this range is from 0.92 to 0.90 and for magnesium sulfate from 0.71 to 0.55.

In about two-thirds of the experiments with potassium chloride the correct trend of g was obtained, the high experimental error (about five per cent) being unfavorable to the determination of the small change in the osmotic coefficient (about two per cent). In every case, however, the correct trend in g was obtained with magnesium sulfate.

In the case of magnesium sulfate a double correction of the solvent was needed since, like other higher valence salts, the hydrated form is the most convenient to use in preparation of solutions. Thus an addition due to the water of hydration is required and a subtraction due to the supercooling effect as shown above. In every case the students made these corrections without error. The questionable exactness of composition of the hydrated salt caused no serious error.

While the above experiments fail to emphasize the accuracy requisite for original contributions in the field of freezing point determination, they are sufficiently quantitative to permit stress of certain points. Thus the relative accuracy of a given measurement needed to achieve a final determination within stated limits of error may be indicated. An introduction to the fundamental elements of the measurement is obtained. Finally, without undue expenditure of time, emphasis upon purification and complications of refined experimentation, the simple picture of normal, associated and dissociated solutes is made more concrete.

The writers wish to acknowledge many helpful suggestions made by Mr. Edgar L. Eckfeldt during the preparation of this study.

[6] GETMAN AND DANIELS, "Outlines of theoretical chemistry," 6th ed., John Wiley & Sons, New York City, 1937, pp. 189–90; 193–5.

PHENOLPHTHALEIN *and* METHYL ORANGE

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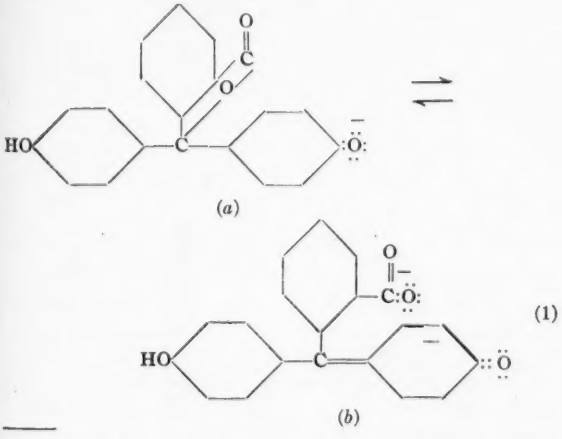
VARIOUS authors are not in agreement on the action of the common indicators. In discussing methyl orange Willard and Furman (*1*) put the hydrogen on the dimethyl nitrogen, while Kolthoff and Sandell (*2*) place it, in the red form, on the azo group. In phenolphthalein the doubt concerns the action of the first equivalent of base. Does it break the lactone ring or neutralize one of the phenolic hydrogens?

The statement of Bury (*4*) that resonance should be responsible for color in these indicators makes certain of the forms ordinarily used at once electronically possible, and others equally impossible. The paper of Wheland and Pauling (*3*) showing mathematically that action on any one point of a molecule changes the electronic condition at other points is stimulating. Supported by these papers we are encouraged to set forth what seems to us a logical explanation of the action of the common indicators.

PHENOLPHTHALEIN

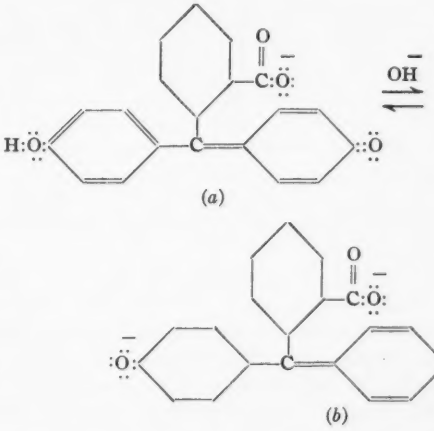
It is frequently stated that the quinoid chromophor is responsible for the color of phenolphthalein; however, Willstätter and Piccard in 1908 (*5*) gave examples of quinoid compounds that were colorless. Acree (*6*) also in 1908 insisted that the phenolate group in addition to the quinoid is necessary for color in phenolphthalein and like substances. Kober and Marshall in 1911 and 1912 (*7*) outlined the actions of phenolphthalein and we find our electronic presentation follows their work rather closely.



(1)

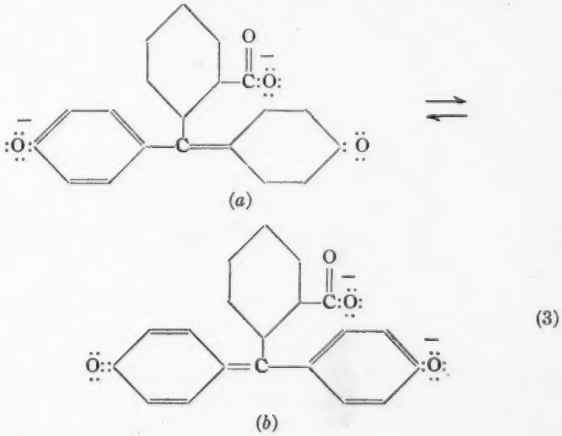
We assume, as did Kober and Marshall (*9*), that the first equivalent of base acts on a phenolic hydrogen leaving a charge on the oxygen as shown in (1*a*). It would appear that the phenolic form of one phenolic group was in equilibrium with the quinoid of the same group. Such a change, however, calls for the breaking of the lactone ring, and the shifting of the charge to the carboxyl as is shown in equation (1).

The second equivalent of base acts on the second phenolic hydrogen, leaving a charge on the oxygen as pictured in equation (2).



(2)

The part of the compound containing the two phenolic groups is now symmetrical and resonance is possible. The resonance forms are given in (3) and show a charge



(3)

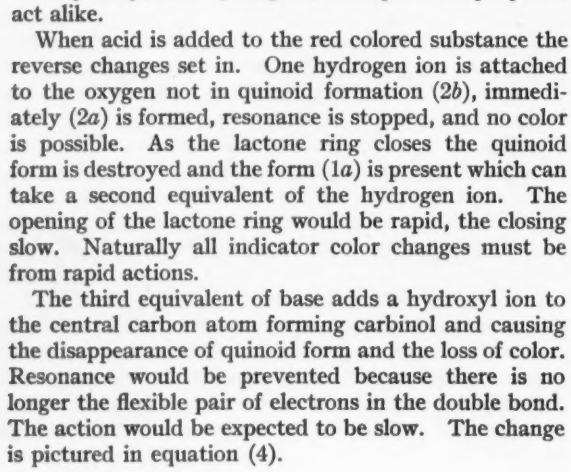
[1] Present address: The American Cyanamid Company, Stamford, Connecticut.

alternately appearing on each phenolic oxygen. The swinging of electron pairs around six atoms, five carbons, and one oxygen, is all that is necessary to make the change.

Because these reactions (1 and 2) are written separately it must not be presumed that reaction (1) is complete before reaction (2) sets in; rather think of a small fraction of the phenolphthalein undergoing reaction (1) and reaction (2) setting in while most of the phenolphthalein is still present as such. No one seems to have been able to prepare either of the salts in equation (1) as would have been the case if reaction (1) was complete before (2) started. Further, as will be mentioned later, Kober and Marshall (*10*) support Green and Perkin in the statement that when the tribasic salt (4*b*) is slowly neutralized, cold, by acetic acid it is necessary to replace two hydrogens before an endpoint can be detected. This might be stated in a different way by saying that the two pK's of the two phenolic hydrogens were nearly the same value and, consequently, both hydrogens, to all practical purposes, act alike.

When acid is added to the red colored substance the reverse changes set in. One hydrogen ion is attached to the oxygen not in quinoid formation (2*b*), immediately (2*a*) is formed, resonance is stopped, and no color is possible. As the lactone ring closes the quinoid form is destroyed and the form (1*a*) is present which can take a second equivalent of the hydrogen ion. The opening of the lactone ring would be rapid, the closing slow. Naturally all indicator color changes must be from rapid actions.

The third equivalent of base adds a hydroxyl ion to the central carbon atom forming carbinol and causing the disappearance of quinoid form and the loss of color. Resonance would be prevented because there is no longer the flexible pair of electrons in the double bond. The action would be expected to be slow. The change is pictured in equation (4).

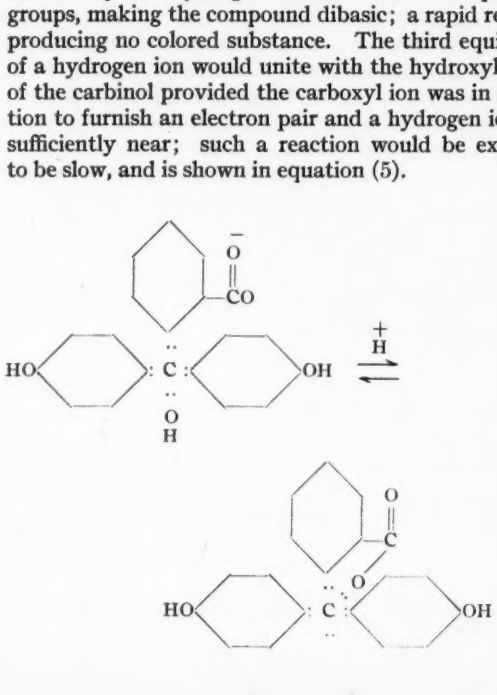


(4)

Lund (*13*) in measuring the rate of fading of phenolphthalein concludes that an excess of hydroxyl ions shows a salt effect and also that the rate is constant in the presence of sodium chloride, the action being what would be expected from the Brønsted theory. In another article Lund (*14*), measuring the rates of fading and color formation in the presence of a hydroxyl ion, finds the rate of fading to be constant while the formation of the colorless compound is shown to be subject to the salt effect.

Assuming equation (4) represents what is happening when the hydroxyl ion combines to form the tribasic salt, it is evident that this equation is supported by Lund's work. To form the colorless substance two ions must find each other, and salts naturally would get in the way, while the production of color requires only the breaking down of one substance. The constant of equation (4) to the right, according to Lund, is several times greater than that to the left, which is what would be expected.

The carbinol form resulting from the combination of the hydroxyl ion from the third equivalent of base is quite stable, for Green and Perkin (*8*) report that if the solution is carefully cooled and slowly neutralized with acetic acid it may be rendered neutral without the return of color. If, on the other hand, the neutralized solution is left for some time or heated the color returns. Green and Perkin further state that tribasic phenolphthalate when titrated with acid is dibasic. Kober and Marshall (*10*) concur when they say that the tripotassium phenolphthalate reacts quickly with two equivalents of acetic acid and decolorizes slowly with the third. To discuss what happens when acid is added to the colorless tribasic salt it is necessary to keep in mind that the carboxyl is a strong weak-acid; stronger than acetic acid as Kober and Marshall (*7*) point out. The first two equivalents of acid then, would replace hydrogen ions on the two phenolic groups, making the compound dibasic; a rapid reaction producing no colored substance. The third equivalent of a hydrogen ion would unite with the hydroxyl group of the carbinol provided the carboxyl ion was in a position to furnish an electron pair and a hydrogen ion was sufficiently near; such a reaction would be expected to be slow, and is shown in equation (5).



(5)

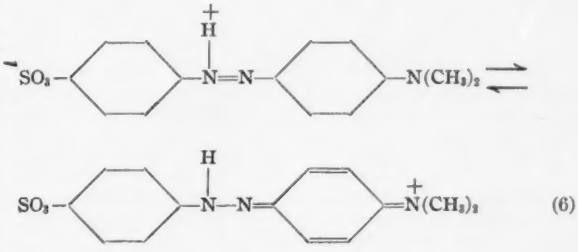
It might be profitable to discuss whether it is the ionized or unionized carboxyl that takes part in the lactone formation. The ionized form is less plentiful, its length is shorter, and a hydrogen ion must be in the immediate vicinity in order that the closing may take place. On the other hand, the unionized form is more plentiful, its length is greater, and no outside elements are needed to effect closure. In equation (5) it was assumed that the ionized form does the closing. In the remainder of this paragraph it will be assumed that the unionized form does the closing. The facts are that Kober and Marshall (*7*) made the colorless mono-salt from the colorless tripotassium phthalate. In water this mono-salt gave a precipitate of phenolphthalein and the solution became colored. The theory says that the dry mono-salt would contain the hydroxyl ion and the sodium ion would be on the carboxyl. Hydrolysis of the mono-salt would replace hydrogen on some carboxyl ions; slowly the lactone ring would close with the elimination of water and phenolphthalein would be formed. The hydroxyl ion produced by hydrolysis of the carboxyl would act in the regular way as pictured in equations (1), (2), and (3) with the formation of the resonating colored forms.

The color of the esters of phenolphthalein support the explanation offered in this paper. When the ester is on the carboxyl the compound is colored as soon as the second equivalent of base acts, while the alkaline solutions of the phenolic esters are colorless as Acree and Slagle (*11*) and others have pointed out. When the ester is on the carboxyl the remainder of the compound is symmetrical after the phenolic hydroxyl ions are gone and resonance is possible, but with the ester on the phenolic group, as with the hydrogen on one phenolic group, the compound is not symmetrical, the electrons, apparently, are not free to move, no resonance results, and consequently no color is seen.

The red color of phenolphthalein fades. Kober and Marshall (*12*) found it impossible to use this substance as a color standard. Certainly the fading of the indicator color at an endpoint is of no analytical significance, but it is interesting that a calculation shows that with as little as 0.01 ml. of 0.1 *N* base present in excess with three drops of 0.1 per cent phenolphthalein solution there are over three times as much hydroxyl ion present as is necessary for the fading change shown in equation (4). Kober and Marshall (*9*) say, "Our figures show that hydration begins with the smallest amount of alkali."

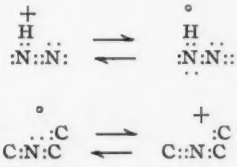
METHYL ORANGE

The two colors of methyl orange would seem to call for two resonating mechanisms. These we have been unable to find by juggling electrons with pencil and paper so we conclude that the two forms usually pictured are the resonance mechanism for the red color, and that the yellow color is due to some other phenomena; further, that the electronic arrangements necessary for resonance require a hydrogen on the nitrogen of the azo group nearest the sulfonic acid radical, and none of the dimethyl nitrogen exactly as outlined by Bury (*4*). The resonating forms responsible for the red color are, then, the changes usually given for the yellow and red forms and are shown in equation (6).



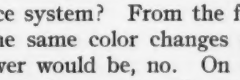
(6)

The simultaneous electronic changes of the azo and the dimethyl nitrogens are pictured during resonance in equation (7).



(7)

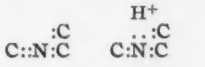
The introduction of an equivalent of base will withdraw the hydrogen from the azo nitrogen, making it neutral, consequently upsetting the resonance mechanism and resulting in the loss of the red colored form. The electronic condition of the azo nitrogen is pictured in equation (8) which shows that while the requisite eight electrons are at all times present



(8)

the addition of H^+ reduces the electronic charge of the nitrogen from five to four.

The question arises, has the sulfonic group any part in the resonance system? From the fact that aminobenzene has the same color changes and no sulfonic group the answer would be, no. On the other hand, the fact that methyl orange is yellow in strong sulfuric acid, becoming red on dilution, is interesting. One line of reasoning, to explain this action, would be to say that the unionized form only existed in the sulfuric acid, and consequently the ionized form was necessary for resonance. Another and better explanation would be to say that the dimethyl nitrogen acted as a base in the sulfuric acid system, and the consequent acquirement of an H^+ would prevent resonance. Such a change would be pictured in equation (9).



(9)

With the free electron pair of the dimethyl nitrogen held by the hydrogen it would not be possible to form the quinoid structure necessary for resonance.

Both the azo and the dimethyl nitrogens would be positive.

It is hoped that these suggestions will aid teachers in their interpretation of the action of the common indicators.

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SILVER PHOSPHATE *in* QUANTITATIVE ANALYSIS

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MOST textbooks of elementary quantitative analysis contain at least one laboratory exercise designed to familiarize students with the properties of silver chloride and its use in gravimetric analysis, and also, by analogy, with other determinations in which the same general technic is applied. The specific analysis usually chosen for study is the determination of chloride, but for instructional purposes a determination of silver is equally useful and much more economical. In the analysis of chloride unknowns by students there is a considerable loss of silver nitrate due to liberal use of excess precipitating reagent, but this is almost literally only a drop in the bucket compared to losses occasioned by the fact that many students do not properly distinguish between silver nitrate solution and water, which after all look very much alike.

Two years ago a gravimetric silver determination was substituted for the chloride determination in the quantitative analytical courses here. With a silver unknown to be analyzed, the loss of even a few tenths of a milligram of silver-bearing material became a matter of direct concern to every student. The amount of silver nitrate used in these courses dropped off so markedly that the new laboratory exercise was retained.

The unknowns given out for analysis at first were mixtures of silver nitrate and sodium or potassium nitrates containing from twenty-five to fifty per cent of silver. The analytical results obtained were excellent, but the unknowns were found to have several undesirable properties. While these mixtures do not absorb moisture in air of moderate humidity, their texture is such that they always seem moist. They are easily light-struck. Every portion spilled on a balance pan develops a permanent stain. Moreover, the grinding and mixing of the samples is a very unpleasant operation, which leaves its mark on everything and everyone concerned for some time.

After a preliminary examination of various silver compounds, the phosphate was selected as the most promising substitute for the nitrate. Ten large samples for student analysis were made up with weighed amounts of pure, dry silver phosphate and well-dried, reagent-grade potassium dihydrogen phosphate to contain between 37.0 per cent and 77.3 per cent of silver. The average percentage of silver found in over one hundred student gravimetric analyses of each sample checked the calculated value to better than 1 part in 500 in all ten cases. The same unknowns were used by students in the volumetric determination of silver with 0.0500 *N* thiocyanate solution by the Volhard method with uniformly good, but less precise, results.

These mixtures containing silver phosphate have none of the objectionable properties of the silver nitrate

unknowns. It is also of advantage that all of the various mixtures have the same bright yellow color as the pure compound.

PREPARATION OF PURE SILVER PHOSPHATE

Silver phosphate that will meet most analytical requirements for purity may be prepared as follows: Dissolve 454 grams of reagent-grade silver nitrate in a liter of distilled water in a 4-liter beaker. Add 70 ml. of 85 per cent phosphoric acid containing 1.44 grams of H_3PO_4 per ml., and filter the solution to remove the slight precipitate which forms, together with any other insoluble impurities. Arrange a stirring motor with a glass propeller to stir the solution, and add 3 *N* chloride-free aqua ammonia slowly and with constant stirring until noticeable precipitation of silver phosphate ceases, or until the pH of the supernatant liquid is about 5.9. About a liter of 3 *N* aqua ammonia should be prepared for this neutralization.

Collect the silver phosphate on a filter in a 10-inch Büchner funnel, and wash it with ten to twenty 500- to 1000-ml. portions of distilled water. Drain the precipitate, applying suction if convenient, and finally dry it to constant weight by 12 to 24 hours' heating on a hot plate, in a 12-inch porcelain evaporating dish under an inverted funnel, raising the temperature gradually from 80°C. to 350°C. or higher. Work the material occasionally with a spatula or mortar and pestle, to break up any lumps.

Using this method of preparation we have obtained yields of 370 to 372 grams of silver phosphate containing from 77.22 to 77.29 per cent of silver. The theoretical yield is 373 grams with a silver content of 77.31 per cent.

SILVER PHOSPHATE AS A PRIMARY STANDARD

Silver phosphate has been recommended as a standard for the determination of phosphate.[1] In the course of the present study we have made analyses to determine its suitability for standardizing potassium thiocyanate solutions for use in Volhard determinations. Four independently prepared samples of silver phosphate were used in standardizing a 0.1 *N* potassium thiocyanate solution, which was then used in analyzing samples of pure silver nitrate.

Samples 1 and 2 of the silver phosphate were made as described above, from ordinary reagent-grade silver nitrate and C.P. phosphoric acid. Sample 3 was prepared similarly, but without precautions designed to remove chloride present in the reagents: only the original silver nitrate solution was filtered, and the ammonia was not distilled. Sample 4 was made from silver nitrate purified as described below, and from phosphoric acid prepared by oxidizing vacuum-distilled phosphorus with pure nitric acid. Distilled ammonia was used to make aqua ammonia for the precipitation. The sample was collected in a Munroe crucible and dried in quartz.

Silver nitrate for the Volhard analyses was purified by precipitation with redistilled 15 *N* nitric acid, using 0.38 ml. of acid per gram of silver nitrate. The silver nitrate solution, saturated at about 60°C., was filtered at about 80° C. The nitric acid was then added and the mixture was allowed to cool to room temperature. The precipitated silver nitrate was centrifuged and dried in platinum, dissolved in distilled water, recrystallized, centrifuged, dried, and fused in platinum.

In all standardizations and analyses the silver salts were dissolved in a little water containing 10 ml. of 6 *N* chloride-free nitric acid, diluted to about 50 ml., and titrated with the thiocyanate solution after addition of 5 ml. of saturated ferric alum solution containing 80 ml. of 15 *N* nitric acid per liter. The results of the various standardizations and analyses are summarized below.

Standardizations				Analyses		
Ag_3PO_4 sample	*Grams Ag_3PO_4*	*Ml. KCNS*	*Normality of KCNS*	*Gm. $AgNO_3$ taken*	*Ml. KCNS used*	*Gm. $AgNO_3$ found*
1	0.4868	34.53	0.1010	0.6014	34.99	0.6016
	0.5040	35.66	0.1013	0.6539	38.06	0.6544
2	0.5029	35.62	0.1012	0.6020	35.01	0.6019
	0.5034	35.70	0.1011			
3	0.4715	33.32	0.1014	(Normality of KCNS used = 0.1012)		
	0.5079	35.93	0.1013			
4	0.5023	35.57	0.1012			
	0.5233	37.06	0.1012			

These experiments show that silver phosphate may easily be prepared in pure form, and that it is a good primary standard for Volhard determinations.

[1] DUMAS, *Chem. Eng.*, **12**, 185 (1910); *Chem. Analyst*, **8**, 12.

Robert Bunsen, while on the faculty of the University of Marburg, received an invitation to take part in a scientific expedition to Iceland. In order to leave his post and make the journey he needed the permission of the Kurfürst. But the latter was a cantankerous old man and never seemed to get around to it. Time became short and it finally became necessary to resort to a ruse: Bunsen had a cousin who was physician to the Kurfürst and who went to the old man in great trepidation, saying that he had a cousin, a professor at the University, who wanted to go to Iceland. His friends feared, however, that since it was a very hazardous journey he would undoubtedly lose his life in the venture. Next day Bunsen received the necessary papers!

The SIGN *of* ELECTRODE POTENTIAL

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ONE of the more difficult tasks for the student of physical chemistry is the mastery of the group of conventions which determine the sign of the electromotive force in a galvanic cell. Part of this difficulty arises from the fact that the convention was reversed some years ago, assigning to the metals above hydrogen in the electromotive series a negative sign in place of the positive sign they had previously borne. Since some texts and charts still use the earlier convention, it is inevitable that some confusion should result. The system which is described has been in use in the author's classes for several years with some success. It has the advantage of being easily understood and of correlating with the thermodynamic derivation.

CONVENTIONS IN THE WRITING OF GALVANIC CELLS

Suppose the cell to be written in the usual form

$$\text{Zn} \mid \text{ZnSO}_4\ M/10 \parallel \text{KCl saturated} \parallel \text{CuSO}_4\ M/10 \mid \text{Cu} \qquad (1)$$

The reaction occurring in a cell may be invariably had by taking as reactants the reducing or lower valence substance from the left-hand side of the cell as written and the oxidizing or higher valence substance from the right-hand side. Thus

$$\text{Zn} + \text{CuSO}_4 \longrightarrow \text{ZnSO}_4 + \text{Cu}$$

With the cell written in this fashion, it is indicated that the ordinary or spontaneous cell reaction will involve the solution of the zinc electrode to form zinc sulfate and the deposition of an equivalent amount of copper from the solution upon the copper electrode.

For this reaction to be a spontaneous one, the cell reaction must involve a loss in free energy content in the system, which loss is equal to the electrical work done by the cell when operating isothermally and reversibly. These conditions are attained when the cell delivers an infinitely small current against an infinite resistance at constant temperature. The free energy loss is represented by the equation,

$$-\Delta F = nFE \qquad (2)$$

where E is the cell potential, n is the number of Faradays required to convert the molar quantities in the equation, and F is the number of coulombs per Faraday.

Considering the right-hand electrode alone for the time, the free energy of transfer from metal ion to metal lattice may be represented as occurring in two steps: (1) the transfer of the ion from its activity in the solution to unit activity, and (2) the transfer of the ion from unit activity to the normal unstrained lattice of the pure metal. The equation is

$$nFE = -\Delta F = 2.302RT \log \frac{a_{Cu^{++}}}{a = 1} + 2.302RT \log \frac{a = 1}{a_{pole}} \qquad (3)$$

The second term of this equation has no quantity which is characteristic of the particular solution about the electrode, or, if the electrode is properly prepared, of any particular electrode. This term is, therefore, a property of the system copper-copper ion and is a constant at constant temperature. When both sides of the equation are divided by nF, the second term has the dimension of voltage and is represented by E_0, the standard potential.

$$E = 2.302 \frac{RT}{nF} \log a_{Cu^{++}} + E_0 \qquad (4)$$

In order for the left-hand or zinc electrode to forward the same reaction as the copper, transfer of ion must occur in the opposite direction; *i. e.*, from electrode to solution. Equation 4 applies to this reaction also but with the signs just reversed since the transfer is in the reverse direction. The cell potential may then be calculated by subtracting the potential of the left-hand electrode from that of the right-hand electrode.

Thus,

$$E_{cell} = E_{0Cu} + 2.302 \frac{RT}{nF} \log a_{Cu^{++}} - E_{0Zn} - 2.302 \frac{RT}{nF} \log a_{Zn^{++}} \qquad (5)$$

Since the activity coefficients of $M/10\text{CuSO}_4$ and $M/10$ ZnSO_4 are each approximately 0.16,

$$E_{cell} = 0.3441 + 0.0591 \log \frac{0.016}{0.016} - (-0.7618) - 0.0591 \log \qquad (6)$$

$$E_{cell} = 0.3441 - 0.0531 + 0.7618 + 0.0531 = 1.1059 \text{ volts} \qquad (7)$$

Since the positive potential of the cell indicates a loss in free energy, a cell reaction which gives a positive cell potential is one which occurs spontaneously. In such a cell a continuous passage of electrons from the right-hand electrode to the solution is necessary to permit the deposition of ions at this point. The current, therefore, flows from right to left in the cell.

The procedure followed in the case above is directly applicable to every type of cell, necessitating only one equation and one method of treatment. To demonstrate the applicability of the convention, the following types of cells are considered.

THE CELL REACTION IS NOT SPONTANEOUS

Suppose the cell were as follows:

$$\text{Cu} \mid \text{CuSO}_4\ M/10 \parallel \text{KCl}\ (M)\ \text{Hg}_2\text{Cl}_2 \mid \text{Hg}$$

The cell reaction is

$$Cu + Hg_2Cl_2 \longrightarrow CuCl_2 + 2Hg$$

The cell potential is

$$E_{cell} = 0.2805 - E_{0Cu} - 2.302\frac{RT}{nF}\log 0.016 \quad (8)$$

where 0.2805 is the potential of the normal calomel electrode.

$$E_{cell} = 0.2805 - 0.3441 + 0.0531 = -0.0105 \text{ volt} \quad (9)$$

The free energy is

$$-\Delta F = -0.0105 \times 2 \times 23050 = -485 \text{ calories} \quad (10)$$

which indicates that the reaction as written is not spontaneous. In this case the right-hand electrode is negative and the current flows from left to right inside the cell.

OXIDATION-REDUCTION CELLS

In certain instances, the electrode serves only as a carrier for the introduction of electrons into the solution or for their removal from the solution. Such an electrode furnishes no ions and is referred to as an inert electrode. This designation is, perhaps, not altogether correct since the character of the electrode surface may have an effect upon the reversibility of the reaction. Among the electrodes which are employed in this way are gold, platinum, and carbon.

Suppose that we have as the cell reaction

$$Ce^{++++}\ (a = 1) + Fe^{++}\ (a = 0.005) \rightarrow Ce^{+++}\ (a = 0.02) + Fe^{+++}\ (a = 0.1)$$

Following the rule previously formulated, the cell is written

$$Pt \mid Fe^{++}\ (a = 0.005), Fe^{+++}\ (a = 0.1) \parallel Ce^{+++}\ (a = 0.02), Ce^{++++}\ (a = 1) \mid Pt$$

At the right-hand electrode, the reaction is

$$Ce^{++++} + e = Ce^{+++}$$

$$-\Delta F = nFE = 2.302RT\log\frac{a_{Ce^{++++}}}{a_{Ce^{++++}{}_s}} + 2.302RT\log\frac{a_{Ce^{+++}{}_s}}{a_{Ce^{+++}}} + 2.302RT\log K \quad (11)$$

This is done by assuming that the ceric ion is transferred from its activity in the solution to unit activity, converted to cerous ion at unit activity, and the cerous ion transferred to its final activity in the solution.

A rearrangement of this equation gives

$$-\Delta F = nFE = 2.302RT\log\frac{a_{Ce^{++++}}}{a_{Ce^{+++}}} + 2.302RT\log K \quad (12)$$

The second term of this equation involves the free energy of reduction of the ceric ion at unit activity which is a property of the ceric-cerous system and, therefore, constant at constant temperature. The equation becomes

$$-\Delta F = nFE = 2.302RT\log\frac{a_{Ce^{++++}}}{a_{Ce^{+++}}} + nFE_0 \quad (13)$$

$$E = E_0 + 2.302\frac{RT}{nF}\log\frac{a_{Ce^{++++}}}{a_{Ce^{+++}}} \quad (14)$$

It is apparent that the sign of the second term is invariably positive and that the ratio is that of the activity of the oxidant to the activity of the reductant.

Since the left-hand electrode must react in reverse direction to carry on the cell reaction, the potential of the left-hand electrode is subtracted from that of the right-hand electrode as before.

$$E_{cell} = E_{0(Ce^{++++},\ Ce^{+++})} + 2.302\frac{RT}{nF}\log\frac{a_{Ce^{++++}}}{a_{Ce^{+++}}} - E_{0(Fe^{+++},\ Fe^{++})} - 2.302\frac{RT}{nF}\log\frac{a_{Fe^{+++}}}{a_{Fe^{++}}} \quad (15)$$

Now

$$E_{0(Ce^{++++},\ Ce^{+++})} - E_{0(Fe^{+++},\ Fe^{++})} = 2.302\frac{RT}{nF}\log 1/K \quad (16)$$

where K is the equilibrium constant for the reaction.

OXIDATION-REDUCTION INVOLVING THE HYDROGEN ION

The Quinhydrone Electrode.—When quinone is brought into contact with a negative electrode in the presence of hydrogen ion, it is reduced to hydroquinone.

$$C_6H_4O_2 + 2H^+ + 2e \rightleftarrows C_6H_4(OH)_2$$

This is one of the few organic oxidations and reductions which are reversible.

We may assume as in the previous case that the oxidant is transferred from its initial activity to unit activity, reduced from quinone at unit activity to hydroquinone at unit activity and the hydroquinone transferred to its final activity. Now, in a solution saturated with quinhydrone, the activities of quinone and hydroquinone are equal and the only free energy terms are those involving the reduction of quinone at unit activity and the transfer of two moles of hydrogen ion from the initial activity to unit activity.

$$E_{single\ potential} = E_{0quinhydrone} + 2.302\frac{RT}{2F}\log(a_{H^+})^2 \quad (17)$$

Cancelling the exponent of the hydrogen-ion activity against the valence change in the denominator

$$E_{single\ potential} = E_{0quinhydrone} + 2.302\frac{RT}{F}\log a_{H^+} \quad (18)$$

When the left-hand electrode is the saturated calomel electrode, at 25°C.,

$$-\log a_{H^+} = \text{pH} = \frac{E_{0quinhydrone} - E_{single\ potential} - E_{calomel}}{0.0591} \quad (19)$$

CONCENTRATION CELLS

A cell may be constructed with two identical electrodes in contact with an electrolyte which has different concentrations in the two halves. Since this differs only in the activity of the ion in the electrolyte, such cells are called concentration cells. Similarly concentration cells may be constructed with electrodes having different activities of the metal but in contact with a common electrolyte.

Let us consider the cell:

$$Ag \mid Ag\,NO_{3_{a_1}},\ M/100 \parallel Ag\,NO_{3_{a_2}},\ M/10 \mid Ag$$

Using our convention,

$$E_{cell} = E_{0_{Ag}} + 0.0591 \log a_2 - E_{0_{Ag}} - 0.0591 \log a_1 \quad (20)$$

Since the electrodes are identical, the standard potential cancels and

$$E_{cell} = 0.0591 \log \frac{a_2}{a_1} \quad (21)$$

Now for a cell of the opposite type, we have:

$$\begin{array}{l|l|l} Pb\ amal. & PbSO_4\ sat. & Pb\ amal. \\ Pb = a_1 & Pb^{++} = a_1 & Pb = a_{11} \end{array}$$

Using our convention, and remembering that it is necessary to transport the metal in the electrode to the activity of the metal in the normal lattice before converting to lead ion;

$$E_{cell} = 2.302 \frac{RT}{nF} \log \frac{a_1}{a_{11}} - 2.302 \frac{RT}{nF} \log \frac{a_1}{a_1} \quad (22)$$

$$E_{cell} = 2.302 \frac{RT}{nF} \log \frac{a_1}{a_{11}} \quad (23)$$

CONCLUSION

A convention for the sign of the potential of a galvanic cell based on free energy changes at the electrodes has been presented. The convention has the advantage of being independent of the direction of the current flow and of applying uniformly to all cases. A number of applications have been cited.

A SEPARATION METHOD AND QUALITATIVE TEST FOR CADMIUM ION INVOLVING ALKALINE TARTRATE COMPLEXES

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OF THE common cations only cadmium, ferric, magnesium, and the alkaline earth ions are dissolved in cold alkaline tartrate solutions but reprecipitated upon heating. All the other common cations either are insoluble or form solutions stable to heat. Advantage has been taken of this property of cadmium to devise a method of separating it from the other ions of the copper sub-group in the hydrogen sulfide procedure. Of these ions, mercuric is insoluble in the reagent while lead, bismuth, and copper form solutions stable to heat.

Two alternative procedures have been successfully applied in a student qualitative analysis course.[2] The first of these is to divide the solution, after the removal of lead as the sulfate, into two portions. One of these is tested for bismuth and copper in the usual manner, the other for cadmium. Sample directions are given for a semimicro scale. To one ml. of sample add one ml. of 1 *N* Rochelle salts solution, neutralize excess H_2SO_4 and make about 0.5 *N* with excess NaOH.[3] The resulting solution should be clear. Upon boiling a white precipitate of $Cd(OH)_2$ results. For further confirmation the copper ion may be removed by washing and the precipitate converted directly to the sulfide. The most serious objection to this procedure is that the rather large amounts of H_2SO_4 usually present after the removal of lead may cause so much heat to be generated in the process of neutralization that a clear solution will not be obtained. This will not seriously affect the test unless the removal of the earlier appearing ions has been incomplete. It is recommended that the neutralization be carried out with cooling.

The alternative method is applied after the removal of bismuth by ammonium hydroxide. To the ammoniacal solution add one or two ml. of Rochelle salts solution and excess NaOH. Upon boiling to remove ammonia $Cd(OH)_2$ is precipitated. Further confirmation may be made as in the first procedure.

Extremely large excesses of copper ion affect the sensitivity. Not less than one part in 10,000 of cadmium ion must be present in solutions containing 20 parts in 10,000 of copper ion for the test to work successfully. The practical limit under ordinary conditions is about one part in 100,000 of cadmium ion. The test seems to be more sensitive than this but the problem of visibility of the precipitate as it forms and of centrifuging to carry out the confirmation test sets this as a working limit. The test is certainly not as sensitive as the sulfide in very dilute solutions.

The chief advantage of the test is that it is more free from interference than any of the common procedures. In the absence of ferric, magnesium, and the alkaline earth ions only cadmium will give the first test outlined regardless of the point in the procedure at which it is introduced. The use of the sulfide as further confirmation makes the test applicable in the presence of any common ion[4] except ferric.

[1] Present address: Ohio State University, Columbus, Ohio.

[2] The author wishes to thank Professor T. H. Hazlehurst and his students for their coöperation in the testing of the procedures.

[3] The concentration suggested for NaOH is not given as an exact requirement for the test but as the best lower limit for the excess added. Higher concentrations in excess and somewhat lower limits seem to make very little difference in the success of the test.

[4] The term common ion is taken to cover: Ag^+, Hg_2^{+2}, Hg^{+2}, Pb^{+2}, Bi^{+3}, Cu^{+2}, Cd^{+2}, Sn^{+2}, Sn^{+4}, As^{+3}, Sb^{+3}, Fe^{+2}, Fe^{+3}, Co^{+2}, Ni^{+2}, Mn^{+2}, Al^{+3}, Cr^{+3}, Zn^{+2}, Ba^{+2}, Sr^{+2}, Ca^{+2}, Mg^{+2}, Na^+, K^+.

An IMPROVED FORM *of* VAPOR DENSITY APPARATUS

JAMES M. HENDEL AND OTTO OCHSENREITER

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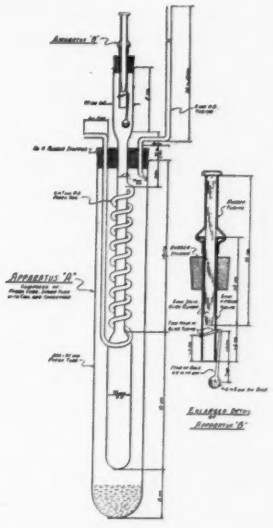
An improved form is suggested for the Victor Meyer vapor density apparatus, including a simple and "sure fire" breaking device. Using this apparatus and following certain precautions, we have determined molecular weights with a precision of two per cent and a great gain in dependability. The sources of error have been investigated and for the most part eliminated. Unknown liquid mixtures are recommended as the best test of student performance.

✦ ✦ ✦ ✦ ✦ ✦

THE determination of vapor density by the method of Victor Meyer is an experiment included in practically all courses in physical chemistry. It is of recognized value in giving the student experience in handling gases and applying the gas laws to some definite end. Yet this classic experiment proves a stumbling block for most students. With a view to removing most of the difficulties a new form of apparatus was devised which has certain advantages over the older types and gives more consistent results.

The apparatus shown in diagram *A* consists of a pyrex test tube 400 × 50 mm. serving as the steam jacket for an improved vaporization tube. Since it is the jacket that is most often broken, the test-tube form is a great advantage, being more resistant to heat and mechanical shock and less expensive to replace. The inner tube is compact so that practically all of it is exposed to the steam, yet because of the spiral it provides a comparatively great distance for the vapor to travel before it reaches the exit. In this form, the distance from the bottom of the bulb, where the vapor is formed, to the side exit is 126 cm. compared to 52 cm. for the older form and 67 cm. for the Weiser modification.[1] The spiral tube is fitted into the rubber stopper so that it is immovable and may be lifted out of the jacket with the stopper. This latter also carries a 9-mm. glass tube about 30 cm. long, to serve as an air condenser for the steam.

The glass tube and plunger device shown in diagram *B* is arranged to hold the bulblet containing the liquid to be vaporized in the cooler part of the apparatus until temperature equilibrium is established, when the plunger is operated to break the bulblet. It is well known that the bulbs usually do not break if simply dropped into the vaporizing tube, and if they do, the air is forced over too quickly to be collected. So that the liquid will distil gradually and thereby displace the air slowly, it is necessary to keep the liquid cool and to break only the capillary neck of the bulb.



VAPOR DENSITY APPARATUS WITH "SURE FIRE" BREAKING DEVICE

Other breaking devices have been tried which involve loosening the stopper or pulling up on it to break the bulb. For the skilled operator these are satisfactory, but the average student either fails to close the tube tightly or to insert the stopper to the same depth as it was before breaking the bulb. A difference of 1 mm. in the depth to which the stopper is inserted causes an error of 0.25 cc. in the air collected.

The bulblet should be blown to hold about 0.1 gram of liquid; an outside diameter of 6–8 mm. is satisfactory. Its stem should be a capillary not over one mm. outside diameter and bent at an angle to fit the holes (2-mm. diameter) in the glass tube from which it is hung. For ease in breaking, a fine stem is an advantage, but if the bore is too small the vaporization may be so slow that diffusion of the vapor may occur and too little air be displaced. The overall length of the bulb may not be more than 40 mm., as it must hang in the cooler part of the tube. This part of the tube may attain a temperature of 35°C. and if the liquid be very volatile it may spray out when the bulb is broken and invalidate the

[1] WEISER, *J. Phys. Chem.*, **20**, 532 (1916).

experiment. For the same reason the bulb should not be entirely filled so that if appreciable expansion occurs on heating the capillary will still be empty.

If it is desired, a small water jacket may be fitted over the projecting part of the vaporizing tube and a current of cold water used to keep the liquid in the bulb well below its boiling point. Keeping this part of the tube at a constant temperature also aids in securing the pressure equilibrium necessary for the success of the experiment.

Equality of pressure before and after vaporizing the liquid can only be maintained if the temperature of the inner tube is kept constant. This condition requires that the water in the jacket be boiled steadily throughout the preliminary heating and the vaporization, that none of it should be boiled away, and that the tube should not touch the boiling water or the sides of the jacket. Usually ten minutes' heating suffices to bring the air in the vaporization tube to 100°C. and in another five minutes equilibrium is established throughout the system. After the bulb is broken the vaporization is ordinarily complete in one minute for ether, five minutes for chloroform or methyl alcohol, and from five to ten minutes for benzene or carbon tetrachloride depending on the amount taken. In any case the heating should not be prolonged unnecessarily lest diffusion occur.

The displaced air is collected in a eudiometer over distilled water which has been saturated with air. This latter precaution is necessary because 50 cc. of water at room temperature can dissolve 2 cc. of air. The air in the eudiometer will have been cooled in its passage through the water so that as soon as the last bubble has come over, the eudiometer may be disconnected and the temperature, pressure, and volume of the displaced air may be measured.

The pressure of the air in the eudiometer is given by the equation

$$P = B_0 - \frac{\Delta L}{13.6} - \frac{100 - h}{100} F \qquad (1)$$

where B_0 is the barometer reading corrected for temperature and latitude, ΔL is the difference in water levels inside and outside the eudiometer expressed in millimeters, h is the percentage relative humidity of the laboratory air, and F the aqueous tension at the temperature of the water in the eudiometer.

The air in the eudiometer is presumed to be saturated with water vapor since it comes over bubble by bubble. The full value of the aqueous tension F, however, is not deducted from the total pressure but a certain fraction of it, $\frac{100 - h}{100} F$ as suggested by Evans.[2] The humidity is determined by the wet-dry bulb thermometer method. Considerable variation in the value of h results if the thermometers are ventilated or not, and this uncertainty in h produces the main error in the pressure measurement. For example, fanning the thermometer gave a value of thirty-five per cent for the relative humidity compared with a value of forty-four per cent without fanning. At 26° where the value of F is 25.7 mm., the term $\frac{100 - h}{100} F$ equals 16.7 mm. for a humidity of thirty-five per cent and 14.4 mm. if forty-four per cent is used. The difference of 2.3 mm. is ten times the probable error in the barometer reading. Neglecting to ventilate the thermometer may therefore introduce an error in the net pressure P equal to 0.3 or 0.5 per cent depending on what values of h and F are applicable.

The molecular weight of the liquid is calculated by the equation

$$M = \frac{W \times T \times 760 \times 22{,}400}{V \times P}$$

where W is the weight of the liquid, V the observed volume of air, T its absolute temperature, and P the pressure found from equation (1). In the experiments tabulated below the observational errors range from 0.1 to 0.3 per cent in W, 0.1 to 0.5 per cent in V, 0.1 to 0.3 per cent in T and about 0.3 per cent in P. The maximum error in M should therefore be 1.4 per cent and the probable error 0.7 per cent. Considering the simple gas law to be valid to one per cent which affects the value of the constant 22,400, the total error in M may be as much as two per cent. Discrepancies greater than this must be attributed to leakage or faulty vaporization, both being apt to cause high values for the molecular weights.

Table 1 shows the results obtained with the new vaporizing tube, using reagent grade liquids, the chloroform having been redistilled after drying over lime. The last two values for chloroform show that large sample weights lead to high results. This may be due to the longer time required for vaporization with consequent chance for diffusion, or because the volume of the vapor formed at 100°, (72 cc. and 85 cc., re-

TABLE 1

Liquid	*Wt., mg.*	*M, obs.*	*M, calcd.*	*Diff.*
$(C_2H_5)_2O$	64.7	74.3		
	71.7	77.2		
		Av. 75.8	74.0	1.8
CCl_4	125.5	152.7		
	102.8	147.5		
	155.0	161.0		
		Av. 153.7	153.8	0.1
C_6H_6	46.3	78.2		
	75.1	82.5		
		Av. 80.4	78.0	2.4
$CHCl_3$	37.4	120		
	57.6	124		
	60.0	122		
	77.1	121		
	86.5	117		
	90.5	116		
	177.8	119		
	230.7	125		
	295.0	(132)		
	342.5	(130)		
		Av. 120.5	119.4	1.1

[2] EVANS, *J. Am. Chem. Soc.*, **35**, 958 (1913).

spectively) exceeds the capacity of the bulb, 70 cc. Although the spiral part of the tube offers an additional 45 cc. of available space, yet it is apparent that diffusion and condensation have taken place. The values found for the other liquids show that two per cent is the precision to be expected of this apparatus, as the average deviations and the differences between the observed and theoretical values are usually of this magnitude.

In this laboratory it is the practice to issue unknown liquids or mixtures of liquids to students. With a view to testing the procedure as it would be used in regular class work, one of us filled and sealed the bulbs with liquids entirely unknown to the other operator who then carried out the rest of the experiment. The results are shown in Table 2.

TABLE 2

Liquid	*Wt., mg.*	*M, obs.*	*M, calcd.*	*Diff.*
1	67.0	78.5		
(C_6H_6)	100.1	80.0		
	105.1	83.0		
		Av. 80.5	78.0	2.5
2	62.1	161		
(CCl_4)	96.2	146		
	112.0	160		
		Av. 156	154	2
3	38.2	32.9		
(CH_3OH)	57.1	33.5		
	59.4	33.1		
		Av. 33.2	32.0	1.2
4	36.0	74.5		
($C_2H_5)_2O$	71.1	74.6		
		Av. 74.6	74	0.6
5 (*a*)	55.7	62.1	61.5	0.6
6 (*b*)	68.9	76.1	75.9	0.2

(*a*) Mixture of CH_3OH and $CHCl_3$ 1:1 by volume
(*b*) Mixture of CH_3OH and $CHCl_3$ 1:2 by volume

The "molecular weight" of a mixture may be calculated from the equation

$$M = \frac{M_1 M_2 W}{w_1 M_2 + w_2 M_1}$$

where w_1 and w_2 are the actual weights of the two pure liquids, M_1 and M_2 their respective molecular weights, and W is the actual weight of the mixture of average molecular weight M.

For example Liquid Number 6 in Table 2 was a mixture composed of one volume of methyl alcohol to two volumes of chloroform. The densities being 0.792 and 1.489, respectively, $w_1 = 0.792$ g., $w_2 = 2.978$ g., and $W = 3.770$ grams. The calculated value for the "molecular weight" therefore is

$$M = \frac{119.4 \times 32 \times 3.770}{(0.792 \times 119.4) + (2.978 \times 32)} = 75.9$$

Thus by choosing suitable liquids, mixtures can be prepared for class use which are truly "unknown" since they cannot be analyzed simply by their odor. Methyl alcohol (B.P. 66°) and chloroform (B.P. 61°) may be mixed in various proportions to give "molecular weights" ranging from 32 to 119. Similarly acetone (B.P. 57°) may be mixed with chloroform to give values between 58 and 119. These liquids are recommended because of their close boiling points and widely divergent molecular weights. The vapor pressures being approximately the same, there is little tendency to fractionate on standing. In filling the bulbs with suction, however, it is advisable not to prolong the evacuation unnecessarily.

The use of such mixtures serves as a challenge to the student as well as a test of individual performance. With the procedure herein described, the results with classes for the past two years have indicated an increase in precision and considerable gain in consistency over the apparatus heretofore used.

GRADUATE ASSISTANTS AT THE UNIVERSITY OF PITTSBURGH

THE following have been appointed to graduate assistantships in the Department of Chemistry, University of Pittsburgh, for the college year 1940–41: A. Richard Baldwin, B.S. John B. Stetson University, 1940; Charles C. Nathan, B.S. Rice Institute, 1940; Vete Nowosinske, A.B. University of Kansas, 1939; William F. Offutt, B.S. Grove City College, 1940; and Joseph Jackson Rothermel, B.S. Franklin and Marshall College, 1940.

When possible, Bunsen avoided appearing at formal functions where he would be obliged to wear a dress suit, decorated with the medals he had received. When he strolled on the streets or appeared at the university or the laboratory he was very plainly dressed. He was a bachelor, and when a suit was worn out he bought each part separately. In consequence, the different parts rarely matched. However, he took particular pride in the selection of his vests. When he purchased a new one, and came into the laboratory, he stopped at our desks, and expected us to make some remark regarding the bright new vest, such as: "Aber Herr Geheimrath, was für eine wunderschöne Veste!" With a pleased expression he would say "Finden Sie?" and then continue with the inspection of the work we were doing. On the other hand, if the student, through oversight, took no notice of the new vest, he went on quickly to the next. Knowing what a pleasure approval of a new vest gave Bunsen, we would spread the report through the laboratory that the Geheimrath had a new one on and due notice thereof should be made.—ALFRED SPRINGER

THE BOILING POINT–COMPOSITION DIAGRAM OF IMMISCIBLE AND PARTIALLY MISCIBLE LIQUID SYSTEMS[1]

MERLE RANDALL AND WILLIAM AVILA

University of California, Berkeley, California

IT IS widely recognized that Raoult's law is obeyed for the solute in the solute-rich layer and for the solvent in the solvent-rich layer in partially miscible liquid systems. If one plots a fugacity[2] or vapor pressure *vs.* mol fraction curve for such a system at constant temperature, he finds that, notwithstanding the very great divergence from Raoult's law for the solute in the solvent-rich layer, and for the solvent in the solute-rich layer (Henry's law regions) the departure from Raoult's law at the other end of the curve is never more than a few per cent, provided the mutual solubility of the liquids is reasonably small. Even in case the mutual solubility of the liquids is relatively great the following method of plotting will yield a temperature *vs.* mol fraction diagram with only a small error. We will assume that the fugacity of a constituent is given by its partial pressure, and that Dalton's law of partial pressure is obeyed.

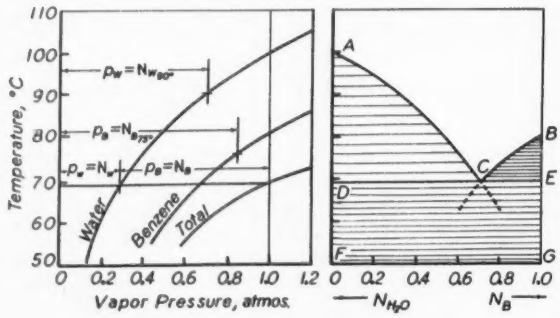


FIGURE 1.—BENZENE–WATER SYSTEM

Left, Temperature *vs.* Vapor Pressure
Right, Temperature *vs.* Mol Fraction

If we designate by P the total pressure, by p_1° the vapor pressure of the pure solvent, by p_1 the partial pressure at its mol fraction N_1 in the solvent-rich layer, by N_1' the mol fraction in the vapor, and by p_2°, p_2, N_2, and N_2' the corresponding quantities in the solute-rich layer, then the total pressure is given by the equation:

$$P = p_1 + p_2 = N_1 p_1^\circ + N_2 p_2^\circ = P(N_1' + N_2') \qquad (1)$$

In the case of mutually very slightly soluble pairs of substances such as benzene and water, the mutual solubility in the liquid phase is so slight that the limit of unsaturated solutions is practically identical with the margins of the diagram. The rate of change of the boiling points of the unsaturated solutions with the composition is enormous. On the left part of Figure 1 we have plotted the vapor pressures in atmospheres of water and of benzene, and their sum against the temperature. As is obvious from the construction, the temperature of the boiling point is that at which the total pressure is one atmosphere, and the composition of the vapor or the mol fraction of a constituent is given by the ratio of its partial pressure to the total pressure, or since the total pressure is one, the mol fraction of benzene in the vapor is equal to its partial pressure. At temperatures above the eutectic boiling point, the mol fraction of the benzene is also given by its vapor pressure, etc. We thus observe that the curve BC in the right-hand part of Figure 1 is identical with the vapor curve of benzene in the left-hand side of Figure 1, and that similarly the curve AC is the vapor pressure curve of water from the left-hand side reversed.

We might have drawn the curve on the right-hand side of Figure 1 immediately by plotting the ratio of the vapor pressure of benzene to the boiling pressure against the temperature, and the ratio of the vapor pressure of the water to the boiling pressure from right to left against the temperature. The boiling point and eutectic composition of the immiscible boiling liquids are thus given by the intersection of the two curves as is indicated. This procedure is valid for any boiling pressure so long as the liquid phases are substantially mutually insoluble and so long as Dalton's law is obeyed.

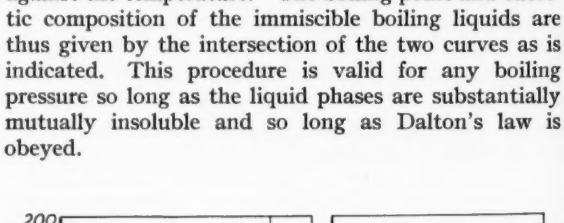


FIGURE 2.—ANILINE–WATER SYSTEM

Left, Temperature *vs.* Vapor Pressure
Right, Temperature *vs.* Mol Fraction

Assuming that the partial mutual solubility of aniline and water are as shown by curves DF and EG in the right part of Figure 2, we can easily construct approximate complete curves for the aniline–water system by a preliminary calculation on the basis of complete im-

[1] Clerical assistance by the Works Progress Administration is gratefully acknowledged. (O.P. 65-1-08-165).

[2] See LEWIS AND RANDALL, "Thermodynamics and the free energy of chemical substances," McGraw-Hill Book Co., New York City, 1923, p. 212.

miscibility. We then have an approximate location of the eutectic temperature along the line *DE*. Hence we draw the branches *AD* and *BE*. As we shall indicate later, slight errors in drawing these curves will cause relatively slight errors in the curves *AC* and *BC*. In the left side of Figure 1 we have plotted the vapor-pressure curves of aniline and water against the temperature, using as the horizontal axis the ratio of the vapor pressure to the boiling pressure. We now transfer the vapor-pressure curve of water to the right-hand diagram, multiplying the vapor pressure of water by the mol fraction of water along the line *BE*, thus obtaining the curve *BC*. Similarly reversing the aniline curve and multiplying by the mol fraction of aniline along the line *AD*, we obtain the curve *AC* of the right-hand part of Figure 2. The intersection gives the vapor composition of the eutectic and the temperature of the boiling partially miscible mixture.

In drawing Figure 2, we assumed that the curve *AD* was a straight line. The curve is probably more nearly like the dotted curve *AD*, by the use of which we find the dotted curve *AC* which does not differ greatly from the curve obtained on the assumption of the straight line.

QUALITATIVE ORGANIC ANALYSIS IN THE ELEMENTARY ORGANIC COURSE

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THE recently published report of the committee of the American Chemical Society on accrediting educational institutions[1] recommends that organic chemistry "should preferably include some qualitative organic analysis, unless a special course in this subject is offered." An experiment in the review of analytical properties of organic compounds proved so successful in the writer's class that the method may prove of interest to other teachers of elementary organic chemistry. The experiment was made easier by the fact that the laboratory manual used had an excellent section on qualitative organic analysis, but it could be carried out without such a section in the manual, if the text used stresses analytical properties sufficiently.

One laboratory period was given to a discussion of the identification of organic compounds by solubility, physical constants, simple reactions, and of elementary analysis for halogen, nitrogen, and sulfur. The class of thirty-three students was divided into four groups for competitive purposes. First, each group of students was given a copy of Kamm's "Qualitative Organic Analysis" and compounds were identified by students asking questions about them, such as solubility in various reagents, boiling point, melting point, and density, which could be answered by simple laboratory experiments. In the second method, the compounds were identified in the laboratory. In the third method, the compounds were identified as in the first one, by the asking of questions, but this time the only reference books allowed were the text[2] and laboratory manual[3] used in the course.

In the tests carried out by asking questions, contests were run simultaneously in two rooms. In these contests, samples of four compounds were given by an instructor to each group at the beginning of the laboratory period. The group in each room identifying all of the compounds with the fewest questions was declared the winner of this contest. The two winners competed for the championship and the two losers had a consolation match. In answering the questions, boiling points and melting points were given within four degrees of the correct values and densities were given within 0.5 per cent of the true values, as errors of the above magnitudes might occur in the laboratory. When Kamm's "Qualitative Organic Analysis" was used as reference, compounds usually were identified in from four to six questions, although most of the compounds were new to the students. One compound, ethylene chlorohydrin, was identified in one minute by the asking of boiling point and density. The third question was, "Is it ethylene chlorohydrin?" Another compound, propylene glycol, also was identified with three questions, but the students had tasted the glycol and by its sweetness had a clue as to its identity. On account of the danger involved in the tasting of organic compounds by elementary students, this method of testing was discouraged.

From the standpoint of teaching class reactions and group solubilities, the above tests, using Kamm's text, were not fully satisfactory, for the students found that in some cases boiling points and density determinations eliminated certain groups. The use of this text did serve to emphasize the fact that every organic compound has its own definite set of properties and may be identified satisfactorily by means of these. The pedagogical value of the contest could be increased by requiring that at least one derivative should be identified before any compound could be reported.

In the test carried out in the laboratory, each group of students was given the same compound at the same time and identification was made as quickly as possible.

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[1] *Ind. Eng. Chem., News Edition*, **17**, 271 (1939).

[2] DESHA, "Organic chemistry," McGraw-Hill Book Co., Inc., New York City, **1936**, 750 pp.

[3] DESHA AND FARINHOLT, "Experiments in organic chemistry," McGraw-Hill Book Co., Inc., New York City, **1938**, 233 pp.

The leader of each group assigned the determination of specific information, as solubility, boiling point, melting point, density, or detection of halogen, sulfur, and nitrogen, to the various students in the group. Written reports were made to the leader, and he, with the assistance of the students who had finished their assigned work, used the data as rapidly as possible to identify the compound or to decide what additional information had to be obtained before it could be identified. The compounds were not identified so readily in the laboratory as by the first method, but *n*-hexyl alcohol was reported correctly in 34, 34.5, 35, and 35.5 minutes, respectively, by the various groups. Succinic acid was reported correctly by one group in 55 minutes. Two groups missed it through poor data or poor calculation of neutralization equivalent. One group did not finish this test. *o*-Dichlorobenzene was reported correctly by three groups in 45, 48, and 50 minutes, respectively, and one group reported *m*-dichlorobenzene instead.

In the third contest, compounds were identified by asking questions, but no reference books were allowed except the text and laboratory manual for the course. Since the boiling points of some branched chain compounds are so near those of homologous lower members, and since sufficient data are not always given in the text to differentiate between such compounds, no branched chain aliphatic compounds were given in the third contest. Most of the compounds given for identification had never been used by the students, but in some cases the odor enabled the students to recognize the class of the compound, and thus to identify it rapidly. Thus caproic acid was identified in two minutes with three questions. In other cases, chance seemed to favor the students in locating the compounds in the text, for benzophenone was identified in three minutes with seven questions. Usually, it took a much longer time for the contestants to choose proper questions in this contest. It took them fifteen minutes to choose the six questions required to identify ethanolamine. Acetoacetic ester was not identified even with eleven questions. However, after the students themselves had become confused about a compound which reacts with sodium and which gives a positive test with hydroxylamine, they could understand better the difficulties organic chemists had forty years ago in explaining the structure of acetoacetic ester.

FRITZ FEIGL (1891—)

(*Frontispiece*)

ANALYTICAL chemistry is now making its principal advances along two lines: the application of organic reagents, and the development of technics requiring no more than minute quantities of the sample being studied. An acknowledged leader in both of these lines of progress is Fritz Feigl, whose name is familiar to all analysts interested in better and more rapid procedures.

He was born in Vienna on May 15, 1891, and studied chemistry there at the Technische Hochschule, a school famed for turning out competent analysts. During the great war he served as an infantry officer on the Russian front and was wounded. His first experiments on systematic qualitative analysis by spot tests were made during his hospitalization. After the war he returned to academic life, and was successively assistant, dozent, and professor (1936) at the University of Vienna, where he held the chair of analytical and inorganic chemistry.

Professor Feigl has made fundamental studies on the relation of definite groups in organic compounds to specific analytical reactions. He based his work particularly on the concepts of coördination chemistry. He can justly be regarded as the founder of the modern movement to utilize organic reagents in the solution of analytical problems, and he is greatly responsible for putting the search for such reagents on a truly scientific basis. These achievements were formally recognized by the Vienna Academy of Sciences by the award of a prize in 1927.

Dr. Feigl has put out about 200 papers on new reagents and improvement of known methods of detection. Since 1920 he has particularly cultivated the development of analysis by spot tests, a province of analytical chemistry that is almost entirely his own creation. His "Qualitative Analyse mit Hilfe von Tüpfelreaktionen," the standard work in this field, appeared in 1931; it passed rapidly through three editions and has been translated into Russian, French, and English. Here are given not only clear directions for making use of spot tests on inorganic and organic materials, but the theoretical section[1] lays down in considerable detail the lines that are likely to prove profitable in the search for new and additional specific tests and reagents. Spot test technic has led to important and entirely new advances in microchemistry, and its value has been acclaimed not only by chemists but also by their biochemical and medical colleagues. The Vienna Academy laureated this work with its first Pregl Prize for Microchemistry.

Dr. Feigl has won an international reputation; he is in great demand as a speaker on his specialty. Chemists from many countries came to his laboratory in Vienna to learn the methodology of spot tests. As one of the founders, and as secretary of the Austrian Microchemical Society, and as editor of various journals dealing with microchemistry, he did much to propagate microanalysis.

When Austria lost its independence in 1938, Dr. Feigl emigrated to Belgium and became director of the research laboratory of the Société Belge de Recherches et d'Etudes at Ghent. The Dutch concern Noury and van der Lande recently organized a laboratory for the study of fine reagents and spot tests, which was put under the charge of Professor Feigl. Following the recent invasion of the Low Countries, however, we understand that he was imprisoned for a period but has subsequently been released.

—*Contributed by Ralph E. Oesper, University of Cincinnati*

[1] This has been issued in English translation (by R. E. Oesper) as a separate volume under the title, "Specific and special reactions for use in qualitative analysis (with special reference to spot test analysis)," Elsevier Publishing Company, (Distributed by Nordeman Publishing Co.), New York City, 1940, 192 pp.

AN APPARATUS FOR PLATING HYDROGEN ELECTRODES

VERNON A. LAMB

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IN A physical chemistry laboratory experiment on the hydrogen electrode, it is desirable for the students themselves to obtain experience in preparing and plating the electrodes. However, if odds and ends of temporarily assembled apparatus are used for carrying out the several steps of the plating process, the procedure is not well adapted to class use. Therefore, the apparatus described herein has been designed for this purpose. The only previously described apparatus for plating hydrogen electrodes of which the author is aware[1] does not appear to be as simple and convenient as this.

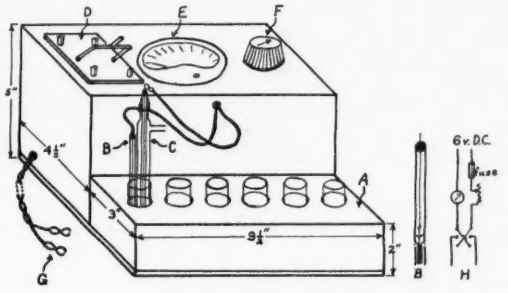


FIGURE 1

A perspective drawing of the apparatus is shown in Figure 1. At *A* is a 2″ × 3″ block bored with six holes for supporting the tubes which contain the plating solutions. These tubes are approximately 1″ × 3″ and are made by cutting off the tops of 1″ × 8″ test tubes. The electrode *B* is soldered permanently to the flexible wire lead shown. As illustrated in the detail drawing, it is made from a strip of platinum foil sealed into 6-mm. glass tubing. The tubing extends to just below the bottom of the foil to protect it from bending or shorting. Two holes in the tube at opposite sides of the upper end of the foil allow escape of gas bubbles. A copper lead is fused to the platinum and cemented in at the top. *C* is an ordinary Hildebrand type hydrogen electrode. Connection to it is made by means of a small spring clip connected to the other flexible lead. Both leads are long enough to permit use of the electrodes in any cup. *D* is a reversing switch, *E* a 500-milliampere ammeter, and *F* is a knob for adjusting the current. For this purpose an ordinary variable radio resistance of 150 ohms, 50 watts, is suitable. At *G* are bulldog battery clips, with polarity indicated, for attaching to a 6-volt storage battery. At *H* is shown the wiring diagram. Figure 2 is a photograph of the apparatus.

An alternative source of direct current is a small transformer and copper oxide rectifier, capable of supplying 0.5 ampere at 6 volts, installed in the back of the box. This arrangement, by eliminating the battery, makes the apparatus entirely self-contained and hence still more convenient to use. All electrical parts required can be obtained from any electrical or radio supply house.

In operation the following solutions are used, one in each tube in the order given: a 6 *N* hydrochloric acid solution for stripping off old black, a 1 *N* sulfuric acid solution for testing cleanliness of the electrode,[1] distilled water for rinsing off acid, plating solution, distilled water for rinsing off plating solution, and 1 *N* sulfuric acid solution for charging the electrode with hydrogen. The electrodes are transferred from one tube to the next. No support for the electrodes is necessary, other than that given by the tubes.

One advantage of the small volume of plating solution required is that accidental spoilage by students is not a serious loss.

Typed instructions for operation of the apparatus are glued to the riser behind the tubes.

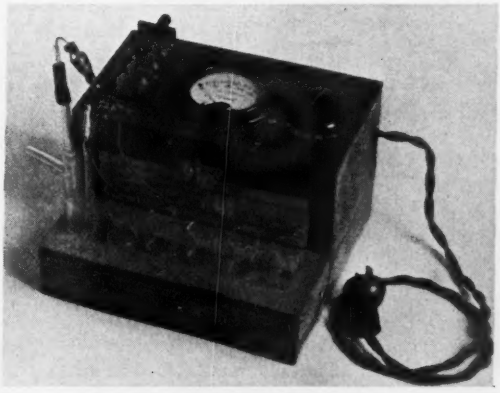


FIGURE 2

We have found the use of palladium black more suitable than platinum black because of the extreme ease with which old deposits may be removed; a few minutes' electrolysis in 6 *N* hydrochloric acid solution is sufficient. We have also experienced less trouble with poisoning of the electrodes since using palladium black.

[1] CLARK, "The determination of hydrogen ions," 3rd ed., The Williams and Wilkins Co., Baltimore, 1928, p. 286.

DETERMINATION OF THE CENTER OF GRAVITY OF THE BEAM OF A CHEMICAL BALANCE

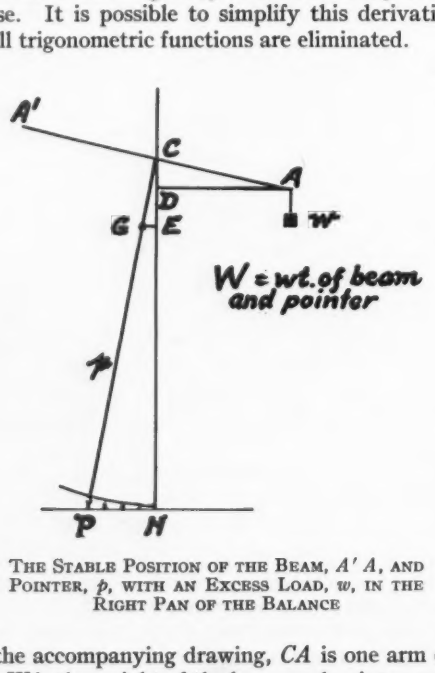
HARVEY V. MOYER

Ohio State University, Columbus, Ohio

A LABORATORY exercise to determine the center of gravity of the beam and pointer of an analytical balance is an excellent method of emphasizing some of the fundamental principles of the theory of the balance. The necessary measurements are easy to make and the derivation of the equation for calculating the distance from the middle knife edge to the center of gravity is quite simple if the sensitivity is measured horizontally along the pointer scale instead of along the arc described by the pointer.

Procedure.—Determine the sensitivity of the balance in the usual way by observing the difference between the zero point of the empty balance and the rest point with an excess load of one mg. on one side. Remove the pans and measure the distance between the two rest points with a small celluloid metric rule placed horizontally along the pointer scale tangent to the arc described by the pointer. Remove the beam and weigh it without the stirrups on a rough balance. Lay the beam and pointer on a sheet of paper and mark the position of the knife edges and the tip of the pointer. Use the marks to measure the distance in millimeters between the knife edges and the distance from the middle knife edge to the tip of the pointer.

Calculations.—The equation for calculating the location of the center of gravity is derived as a part of the exercise. It is possible to simplify this derivation so that all trigonometric functions are eliminated.



THE STABLE POSITION OF THE BEAM, $A'A$, AND POINTER, p, WITH AN EXCESS LOAD, w, IN THE RIGHT PAN OF THE BALANCE

In the accompanying drawing, CA is one arm of the beam, W is the weight of the beam and pointer, w is the excess weight (usually one mg.) in the right pan, G is the center of gravity of the unloaded beam and pointer, CH is the length of the pointer, and PH is the horizontal displacement of the rest point caused by the excess weight, w. It is assumed that the zero point of the empty balance is located at the mid-point of the pointer scale.

If the beam is in stable equilibrium in this position, the moments tending to turn the beam on its axis are equal, hence,

$$w \times AD = W \times GE \tag{1}$$

The right triangles, GCE, PCH, and CAD are similar because they have equal angles, therefore, the ratios of their corresponding sides are equal.

$$\frac{GC}{GE} = \frac{PC}{PH} \text{ or } GC = \frac{GE \times PC}{PH} \tag{2}$$

and,

$$\frac{AD}{CA} = \frac{CH}{PC} \text{ or } AD = \frac{CA \times CH}{PC} \tag{3}$$

Substituting the value of AD in equation (1) and solving for GE gives,

$$GE = \frac{w \times CA \times CH}{W \times PC} \tag{4}$$

Substituting the above value of GE in equation (2) gives the desired form of the equation for expressing the location of the center of gravity of the beam and pointer.

$$GC = \frac{w \times CA \times CH}{W \times PH} \tag{5}$$

The following measurements were made on an Ainsworth Student Type balance:

w = 0.0010 g.
CA = 76 mm.
CH = 242 mm.
W = 35.2 g.
PH = 3.5 mm.

If the above values are substituted in equation (5), GC = 0.15 mm.

Students are surprised to find that the center of gravity is so small a distance below the central knife edge. After making the measurements and calculating the location of the center of gravity it is a simple matter to solve the equation for the sensitivity, PH, thus emphasizing that the sensitivity of a balance is directly proportional to the length of the beam and to the length of the pointer and that it is inversely proportional to the weight of the beam and to the distance of the center of gravity below the middle knife edge.

HIGH-SCHOOL NOTES

A REORGANIZATION OF SECONDARY SCHOOL SCIENCE

FRED FORDEMWALT[1]

University of Iowa, Iowa City, Iowa

IN ARRANGING the science curriculum for the schools of Parsons, Kansas, to fit into the 6–4–4 organization, a careful study of the whole problem of secondary school science was made. The following discussion presents a few of the evidences and conclusions of the study.

The present generation lives in the most fully mechanized period of all time. This machine age is dominated and controlled by the sciences, its creators. Science not only modifies profoundly our life, culture, health, and homes, but influences our modes of thought and, in fact, our whole existence. The dependence upon science is reflected in the growing general interest of the public in scientific matters, clearly indicated by the fact that the circulation of popular scientific magazines has been increasing over twice as rapidly as that for magazines of other types.

This interest arises from a need. The same need has been recognized in our public schools. There is a substantial and increasing agreement among educators that science should occupy a more prominent place in the education of youth and adults alike. The evidence seems overwhelmingly in favor of the contention that the schools are in a far better position to offer the training than is any other of the various channels of dissemination.

Having agreed that some knowledge of science is of the utmost importance for every individual and that the schools are the logical agencies to offer this training, we are still left with some great problems. When, where, and how shall we teach science? What shall be the nature of the courses offered? Shall we teach special or general courses? How much material shall be included in each case? We can hope only to suggest an answer to these questions here, with the acknowledgment that further evidence and experience may modify the position taken. Then, too, many local and administrative situations must be taken into consideration.

As to the kind of courses needed, these must be of two distinct types: those intended as a background or technical foundation for the professional courses and those designed to equip the student better to become an intelligent, useful citizen, in non-scientific professions, in a scientific age. The second type must always be the proper course for the great majority—the majority that will become our average citizens. Gruenberg, in "Science and the Public Mind," has said that: "To vast numbers of men and women science appears as something altogether too remote from their interests or capacities to justify even a glance, or a hope of grasping . . . . The achievements of science as they are forced inevitably upon our attention through the press, the radio, the other concrete applications with which we come in contact, are the achievements of an incomprehensible magic; and most of us are too humble to expect an inside view." It is not too much to hope that this attitude, with its many unfortunate consequences, so common in today's generation, by a proper instruction in the schools of today will be unknown in the generation of tomorrow.

While we shall never be able to justify a requirement that students who plan to become stenographers, bookkeepers, journalists, lawyers, etc., be required to spend hours on end mastering such technical facts and problems as those found in physics and chemistry, we must not overlook the fact that they must have some knowledge and understanding of the broader aspects of the sciences and their impacts upon modern life if they are to serve properly their place in democracy. Likewise, we should no more think of omitting this technical mastery from the requirements for the smaller group who are to enter the professions of engineering, medicine, etc., where such knowledge is basic. There has been a strong, but unfortunate, tendency to allow the entire science curriculum to become dominated by the requirement of this smaller group. The average high-school course tends to be an effort, though somewhat uncertain, in that direction. The average college course is distinctly designed as a technical course. Just where in the school setup the specialized courses should begin may vary with the situation, but it seems generally fitting that all courses below the college level should be broad, non-technical courses with the purpose of stressing scientific attitudes and applications, with more specific data and examples introduced at the higher levels. The courses in the college proper are quite correctly designed as the basic science courses for the professions.

The general acceptance of this distinction should have a wholesome and vitalizing effect on the entire science offering. Despite the recognized significance of science in modern life, we must admit that there has been a strongly apathetic attitude toward it shown by a great mass of our students.

While the suggestion is made that science study should be generalized and liberalized in the secondary schools, it must not be assumed that this indicates we are to be any less serious in our teaching of it. On the contrary, the connotation of this liberalization is a

[1] Present address: 323 East Union Avenue, Bound Brook New Jersey.

new and even greater care in the design of our courses. The liberalized course, to serve the purpose for which it is outlined, is a difficult thing to handle and its proper conduct will require as much or more care in preparation and presentation as work demanding detailed and technical subject matter. Science on the secondary level, though liberalized and generalized, must definitely be "science."

The generalized and broadened science course which seems to be so desirable is quite adequately provided in a survey course. A survey course has been defined as one which cuts across conventional course boundaries and includes at once materials from several fields of learning to accomplish the purpose at hand. In the secondary schools a survey course in biology including and relating the fields of botany and zoölogy, and a survey course in physical science including and relating astronomy, physics, geology, and chemistry, seem to offer splendid opportunities to achieve a large measure of what is expected in secondary schools. In such surveys no need for technical mastery is constantly hovering over either the student or teacher and the broader significance and applications may be freely developed.

Assembling all considerations we may conclude:

(1) No student should complete a secondary education without training in science.

(2) This science should be broad, general, and non-technical, stressing applications and impacts of science as met by the average person in daily life.

(3) Though physics, chemistry, and biology, as separate courses, are of recognized value, the weight of evidence seems to favor a less specialized offering in the high school.

(4) It is suggested that a survey course in physical science, replacing physics and chemistry as such, will contribute to the student the most of value from both, be free from many of their defects, and serve the secondary educational purpose better.

(5) To require that each student complete one unit of biology, as a biology survey course, and one unit of physical science survey seems reasonable for completion of the work of the secondary school.

(6) The eleventh and twelfth years are probably best for these courses, and certainly they should not be given prior to the tenth year. The twelfth year is recommended for the physical science survey.

(7) This recommendation fits into the 6–4–4 organization logically, whereas the more conventional secondary science courses are incompatible with this plan.

(8) Such a science outline also adapts itself well to any secondary school system and eliminates the confusion and lack of correlation between high-school and college science. It would not need to influence the presentation of any survey courses in the college itself

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"A SUGGESTED Course of Study in High-School Chemistry" sponsored by the Division of Chemical Education of the American Chemical Society is one of the outcomes of the 1940 summer Workshop in Chemistry at the Western Reserve University. A copy of the outline will be sent to all teachers who will use it as a basis for teaching and critical study. More information can be obtained from Martin V. McGill, Lorain High School, Lorain, Ohio.

The Second Summer Conference of the New England Association of Chemistry Teachers, held in August at the University of Maine, was one of the outstanding events in chemical education in the East during the summer, due largely to the work of Chairman Theodore C. Sargent of Swampscott, Massachusetts, and his committee. Thirty-five discussion leaders appeared at the ten sessions before a total attendance of well over two hundred. A complete social and recreational program was featured also.

The association has accepted the invitation of the University of Connecticut to hold the Third Summer Conference at Storrs, Connecticut, in August, 1941. George B. Savage of Loomis School, Windsor, Connecticut, is chairman, and Professor Lawrence H. Amundsen of the host institution is in charge of local arrangements.

DOES hydrogen sulfide act on silver? The response to the inquiry[1] about the equation

$$H_2S + 2Ag \rightarrow Ag_2S + H_2$$

which apparently contradicts the electrochemical replacement series of the metals appears to be that the equation is incorrect.

Basing his statement upon extensive experimental data upon this topic, Dr. C. E. White of the University of Maryland reports[2] that he and S. Lilienfeld could detect no hydrogen from this reaction at room temperature; and that unless air and moisture both were present silver was unattacked by hydrogen sulfide except at high temperatures. Evidence is brought forward to support the view that the hydrogen sulfide in solution is oxidized to sulfur. The sulfur then joins the silver readily.

[1] J. CHEM. EDUC., **17**, 148 (March, 1940).
[2] *J. Am. Chem. Soc.*, **52**, 885 (1930).

ERRATA: "SCIENCE PROJECTS"

In the article of this title by R. W. Woline in the August number, a footnote on page 391 refers to the *Illinois Chemistry Teacher*. This should have been the *Science Teacher;* its address is 201 North School Street, Normal, Illinois.

LETTERS

Upper Limit of Temperature

To the Editor:

In the September issue of the JOURNAL OF CHEMICAL EDUCATION, Carl Rosenblum[1] published a paper having the title "Upper Limit of Temperature" in which he made use of the well-known equation for an ideal gas

$$PV = RT = nm\overline{u^2}/3$$

to show that there is a limiting high temperature which cannot be exceeded even in theory. Rosenblum substituted for the speed of the gas particles, u, the velocity of light, c, which is the greatest speed possible for a physical particle and using for m the rest mass, m_0, of the particle, deduced a finite number, $(nm_0c^2)/(3R)$, which he wrote is the "upper limit of temperature" for this gas. Most readers of Rosenblum's paper will be struck by the error in using for m the rest mass m_0 instead of $m_0/\sqrt{1 - u^2/c^2}$ which approaches infinity as u approaches c. There is no upper limit to the temperature on the present Kelvin scale which a gas can conceivably have.

Rosenblum's paper raises the question: Why is there not an upper limiting temperature corresponding to the lower limiting temperature usually referred to as the absolute zero? The answer is that this is a consequence of the way in which our temperature scale was defined.

Before Joule and Lord Kelvin[2] proposed the thermodynamic or Kelvin scale now in use, Lord Kelvin[3] discussed in 1848 a thermodynamic scale of temperatures that extended from $-\infty°$ to $+\infty°$. Temperatures Θ on this first scale are related to temperatures T on the Kelvin scale by the equation

$$\Theta = 100\frac{ln\ T/T_0}{ln\ T_{100}/T_0}$$

where T_0 and T_{100} are the Kelvin temperatures of the ice and steam points. The temperatures of the ice and steam points on the Θ scale are 0° and 100°. Below the ice point, temperatures on the Θ scale are negative and the scale of possible temperatures extends without limit to $-\infty°$. $T°\text{K.} = 0$, $t°\text{C.} = -T_0 \doteq -273.16$ and $\Theta° = -\infty$ are corresponding temperatures for the same thermal state. It can be shown by thermodynamical reasoning that it is physically impossible ever to attain the temperature 0°K. Thus there is a correspondence between the unattainability of 0° on the Kelvin scale and $-\infty°$ on the Θ scale.

That there is no fundamental significance to be attached to the lower limiting temperatures on the Kelvin and Centigrade scales can perhaps be made clearer to the student by calling his attention to the mathematical methods for projecting the whole number scale from 0 to ∞ on another scale extending between any two arbitrarily selected numbers. Thus it is possible to set up an infinite number of different thermodynamic scales on which the whole range of possible temperatures will extend between two arbitrarily selected numbers, temperatures outside the limits of these two numbers being unattainable in theory as well as in practice. For example a thermodynamic scale α related to the Kelvin scale by the relation $\alpha° = \tau - A/T°$ extends from $-\infty$ to $+\tau$ and no temperature above τ on this scale is attainable. By setting $A = T_0T_{100}$ the 100-degree interval between the ice and steam points is preserved. However, the 100 "equal" parts into which the interval is divided on the α scale do not correspond to the 100 "equal" parts into which the interval is divided on the T scale.

The definitions of thermodynamic scales of temperature are based on ideal Carnot heat engines operating in a reversible manner round Carnot cycles composed of two isothermals and two isentropics. Temperatures on the Kelvin and thermodynamic Celsius and Fahrenheit scales are defined by the relation $H_1/H_2 = (C + \theta_1)/(C + \theta_2)$, where H_1 and H_2 are isothermal heats of expansion and compression for the Carnot cycle round which the engine operates, θ_1 and θ_2 are the temperatures of the two isothermals to which H_1 and H_2 refer, and C is a constant. For the Kelvin scale C is 0; for the Celsius and Fahrenheit scales the values of C are determined so that the temperature intervals between the ice and steam points are 100 and 180 degrees, respectively. The heat H_2 of isothermal compression cannot be negative, for this would lead to contradictions of the Second Law of thermodynamics and consequently the lowest possible thermal state is that corresponding to the isotherm for which $H_2 = 0$. The lowest possible temperature, therefore, on any one of these scales is $-C°$. Since H_1, the heat of isothermal expansion, may be infinite, infinite temperatures are theoretically possible. The α scale referred to in the preceding paragraph is defined by the relation $H_1/H_2 = (\tau - \alpha_2)/(\tau - \alpha_1)$. The temperature on the α scale of the isotherm for which H_1, the heat of isothermal expansion, is ∞ is $+\tau°$. Therefore, no temperature higher than $\tau°$ is attainable on this α scale. The isotherm for which the heat of isothermal compression is zero has the temperature $-\infty°$.

The student asks why was the particular thermodynamic scale now in use chosen from the infinite number of possibilities. The answer is: because of convenience and historical background. The first number scales applied to thermometers were defined by making equal changes in temperature correspond to equal changes in volume of the thermometric fluid. These definitions of the temperature scale made the expansivi-

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[1] J. CHEM. EDUC., **17**, 438 (1940).
[2] JOULE AND THOMSON, *Phil. Trans.*, **144**, 321 (1854).
[3] THOMSON, *Phil. Mag.*, **33**, 313 (1848).

ties of the thermometric fluids constant, independent of temperature. Joule and Lord Kelvin[2], in 1854, proposed the particular thermodynamic scale now in use because it corresponds very closely to the mercury-in-glass and gas thermometer scales in use as standards in 1854. This facilitated the adoption of the proposed scientific scale based on the laws of thermodynamics. On the thermodynamic scales *now in use* the expansivities of many substances are approximately constant. In general, this would not be true of other thermodynamic scales.

F. G. BRICKWEDDE

NATIONAL BUREAU OF STANDARDS
WASHINGTON, D. C.

To the Editor:

In the September, 1940, issue of the JOURNAL in an article, "Upper Limit of Temperature," the equation $T = 10^{-7}/25\ Mu^2$ is used in order to determine the highest possible temperature. This equation assumes a constant mass. But Lorentz has shown that as the velocity of light is approached, mass is greatly increased, until it becomes infinite at the velocity of light itself. The equation given by Lorentz:

$$M = \frac{m}{\sqrt{1 - \frac{u^2}{v^2}}}$$

where v is the velocity of light, m is mass at rest, and M is mass at velocity u, when combined with the first equation gives us a new equation:

$$T = \frac{mu^2}{2.5 \times 10^8 \sqrt{1 - \frac{u^2}{(3 \times 10^{10})^2}}}$$

where u is velocity in cm./sec., m is the mass at rest, and 3×10^{10} is the velocity of light in cm./sec.

If the value u is equal to the velocity of light, the temperature becomes infinite. If u for the hydrogen atom is 2.9 cm./sec. the temperature is above 10^{13} degrees Kelvin as compared to the upper limit calculated in the article of 3.58×10^{12} degrees Kelvin.

However, these temperatures are excessive because the hydrogen atom will have ceased to exist at a temperature much lower than this, due to the complete conversion of the mass of the atom into radiant energy. This will be brought about by the radiations of short wave length which characteristically accompany high temperatures, as set forth in the relationship:

$$\text{wave length} \times \text{temperature} = 0.2885$$

The wave length short enough to cause the complete conversion of the hydrogen atom into radiant energy is equal to the wave length of the newly created radiation. By combining the four relationships:

$$\left.\begin{array}{l}\text{energy of quantum of radiation produced by complete conversion of hydrogen atom into radiant energy}\end{array}\right\} = \left\{\begin{array}{l}\text{mass of hydrogen atom} \times (\text{velocity of light})^2\end{array}\right.$$

$$\text{Planck's constant} \times \text{frequency} = \text{energy of quantum}$$

$$\text{speed of light} = \text{frequency} \times \text{wave length}$$

$$\text{temperature} \times \text{wave length} = 0.2885$$

we obtain the equation:

$$T = \frac{0.2885\ mv}{h}$$

where T is the temperature in degrees Kelvin, m the mass of the hydrogen atom in grams (1.666×10^{-24}), v is the velocity of light in cm./sec. (3×10^{10}), and h is Planck's constant (6.5×10^{-27}). In solving we find T to be 2.2×10^{12} degrees Kelvin. At this temperature the accompanying radiation will have a wave length short enough (1.3×10^{-13} cm.) to cause the complete conversion of the mass of the hydrogen atom into radiant energy and the temperature is therefore the highest temperature which the hydrogen atom can reach without being annihilated.

WILLIAM COPULSKY

7901 FOURTH AVENUE
BROOKLYN, NEW YORK

To the Editor:

F. G. Brickwedde correctly brings out in his interesting discussion of temperature scales that we cannot properly speak of an upper or lower limit of temperature. However, this does not preclude the possibility of limiting temperature states for a material body.

The lowest limit which a body can approach has been considered to be 273.16°C. However, no evidence seems to have been offered for a temperature state above which material bodies cannot exist. In order to stimulate discussion on this point, I wrote "Upper Limit of Temperature" (more properly...upper limit of temperature for the hydrogen atom on the Kelvin scale).

In the calculations, I assumed that a mass did not change with increasing velocity and that all the heat energy was transformed into kinetic energy. This was obviously necessary to solve the equation $T = 10^{-7}/25\ Mu^2$. (The Lorentz formula is a theory. A widely accepted one, true, but no rigorous laboratory experiments have been made which eliminate the possibility of producing or assuming a system in which mass is kept constant with increasing velocity.)

It is interesting to note that William Copulsky does not make the assumption of a constant mass. From a consideration of the conversion of mass into radiant energy, he arrives at the temperature of 2.2×10^{12}°K. This is in substantial agreement with the temperature of 3.58×10^{12}°K.

The highest temperatures recorded from measurements of heavenly bodies are from 4 to 5×10^7. The highest temperature which a body can approach under ideal conditions is obviously somewhat higher. So far calculations indicate that it is in the neighborhood of 10^{12}°K.

CARL ROSENBLUM

OLD TOWN RIBBON AND CARBON COMPANY, INC.
BROOKLYN, NEW YORK

Refreshment for the Weary

To the Editor:

. . . That one single line on the bottom of page 311, July issue, gave me enough incentive to read the rather long article entitled, "Some Famous Balances" and enjoy it heartily when I was already tired out and ready to retire after a hard day.

STEPHEN PUTRESKY

HOFSTRA COLLEGE
HEMPSTEAD, NEW YORK

Science Courses vs. Chemistry

To the Editor:

I have read with a great deal of interest both the original article, "A High-School Course in Chemistry that Does Not Lead to Repetition in College," by P. M. Glasoe, and the published responses which followed. Alert teachers of science everywhere have come face to face with the same problem: What science content and activities shall we teach, particularly to the student of somewhat limited ability, of non-academic interests, who probably won't go on to college?

As many other schools have done, we have set up two kinds of science courses clear through the high school (Summit, New Jersey). The college prep people begin with biology in the tenth year, follow with chemistry in the eleventh, and take physics in the twelfth. In these courses we try to teach them humanely, we try to make them challenging, and when we're through, we want our students to know and understand what chemistry really is.

The alternative science courses have been organized as answers to the question, "What science will it profit the average person to know?" In other words, what *functional* knowledges and activities can we organize into interesting and worth-while science courses for the purpose of general education? Every teacher of science knows how little appeal there is (and functional value, too, for that matter) in valence, formula-writing, learning the details of the arc method for making nitric acid, or determining the value of g in the laboratory, especially for boys and girls in the group we are now considering. But these people do have interests and abilities, and science does have values to contribute. It is our job to bring the two together. Perhaps it can be done in a general chemistry course, perhaps it is better done in a general science course. We incline toward the second hypothesis.

It would take far too much time and space to detail what we include in our physical science course. Perhaps it is sufficient to say that this course is not chemistry, yet perhaps forty per cent of its content comes from chemistry; it is not physics, yet another thirty or forty per cent of its content comes from physics; it is not consumer science, yet a large portion of its problems deal with consumer problems of selecting, using, and caring for materials; it is not safety education, yet this is a major goal of instruction. (One teacher, in discussing this course, said, "I don't see how you can teach the chemistry of shutting off a gas valve." Well, you don't. You teach the chemistry of why you shut it off, and then safety education begins at that point.) Other important aspects of science education are also included: conservation; the position of the nation with respect to strategic raw materials and how science can and does help; how science promotes the utilization of waste materials, etc.

We think we're on the right track—or at least *a* right track—there's probably more than one.

R. H. CARLETON

SUMMIT HIGH SCHOOL
SUMMIT, NEW JERSEY

Dibasic Acids Again

To the Editor:

On page 338 of the July issue of the JOURNAL OF CHEMICAL EDUCATION I observe a mnemonic device for recalling the sequence of the names of the saturated aliphatic dibasic acids from oxalic to sebacic, inclusive. The phrase given, "Oh, my, such good apple pie, sweet as sugar," was, as Dr. Teeter says, long used at M. I. T. and I believe that it was devised by the late Professor E. Jewett Moore.

Readers and teachers interested in it may also like the one which I now employ, and which came to me under the inspiration of correcting some quiz papers—"Our Many Students Groping Around Painfully Seeking A Solution."

ERNEST H. HUNTRESS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS

A Name for the Unit of Atomic Weights

To the Editor:

It sometimes seems that one of the most striking things about the science of chemistry and all its hundreds of thousands of names is that one of the most used of all its units is without a name. That unit is the unit of atomic weights. Every freshman chemistry student struggles over the concept of the oxygen atom assigned a weight of sixteen, but no one can tell him the answer when he asks, "sixteen what?"

Why hasn't this unit ever been given a name? There must be a reason, but what is it?

I have seen many beginning students show relief and new comprehension when some word is assigned to this unit and atomic weights explained in such terms. For instance, the word "pel" may be assigned as the name of the unit and the oxygen atom said to have a weight of sixteen pels, and so forth. I know of no serious objections to such usage. It is easier to think with words. Why is it we haven't one for this?

FRED FORDEMWALT

323 EAST UNION AVENUE
BOUND BROOK, NEW JERSEY

100TH MEETING OF THE AMERICAN CHEMICAL SOCIETY

DIVISION OF CHEMICAL EDUCATION

Detroit, September 9–13, 1940

MEETING OF THE EXECUTIVE COMMITTEE

AT A meeting of the Executive Committee, held September 11, 1940, in Detroit, the following action was taken:

(1) Received and accepted treasurer's report.

(2) Approved the recommendation submitted in writing by Wilhelm Segerblom, Chairman, that the Committee on Naming and Scope of Committees be dismissed.

(3) S. R. Brinkley was appointed a member of the Board of Publication for a period of three years, beginning September, 1940, to succeed H. N. Holmes.

(4) Mr. McGill, Chairman, reported that Miss Ernestine M. J. Long of Normandy High School, St. Louis, had been added to the Committee on High-School Chemistry.

(5) Recommend to the Division that provision be made for rotation of membership in each committee.

(6) Authorized following expenditures:

a. $25.00 for expense of Detroit Meeting.

b. $61.43 for labor and materials to produce the book, "Suggested Course of Study in High-School Chemistry," prepared by the High-School Committee.

c. $50.00 to Committee on Examinations and Tests (O. M. Smith, Chairman) for collecting and assembling a reservoir of validated tests.

(7) Approved a charge of $1.00 for each copy sold of "Extra-curricular Experiments for High-School Chemistry Pupils." (This book of experiments was worked out by a group of volunteer teacher-students under the supervision of the High-School Committee.)

BUSINESS MEETING OF THE DIVISION

The business meeting of the Division was held on Thursday afternoon, September 12, at 3:45 P.M.

The secretary reported the action taken by the Board of Publication and the Executive Committee at their respective meetings held earlier in the week.

Motion was carried that the chairmen of all committees submit a list of their respective committees with the idea that one-third be retired and new members be elected at each fall meeting.

Mr. McGill, Chairman, reported on the work of the High-School Committee in the work shop at Western Reserve during the past summer. Report was accepted by vote.

O. M. Smith, Chairman of the Committee on Examinations and Tests, gave a progress report.

The Nominating Committee, consisting of H. N. Alyea, F. H. Martin, and Wilhelm Segerblom, submitted the following slate of officers for the year September, 1940–September, 1941:

Chairman of Division (1940–41)—R. D. Reed

Vice Chairman (1940–41)—N. D. Cheronis

Member at Large of Executive Committee (1940–41)—L. L. Quill

Secretary (for period of three years 1940–43)—P. H. Fall

The report was accepted and the nominees elected by acclamation.

Suggestion was made that hereafter the business meeting be held before the end of the divisional meeting.

The meeting adjourned at 4:15 P.M.

MINUTES OF THE BOARD OF PUBLICATION

A breakfast meeting was held at Hotel Statler at 7:30 A.M., Tuesday, September 10. Present: R. A. Baker, Chairman; M. V. McGill; N. W. Rakestraw; N. D. Cheronis; and P. H. Fall. Also present were H. F. Mack and C. S. Fleck, publishers of the JOURNAL.

By informal discussion it was agreed that the two main lines of work of the Division, as far as publications are concerned, should be:

(1) Twelve monthly issues of JOURNAL OF CHEMICAL EDUCATION (as has been true for a number of years).

(2) Publication of books directly related to Chemical Education.

It was also agreed that the editorship of books as indicated in (2) above should for the present be centered in the present editor of the JOURNAL OF CHEMICAL EDUCATION, and that all questions regarding publication of books by our Division should be referred to him. The group expressed the view that there is an imperative demand that at least one book per year be published.

It was urged that we publish in midsummer a booklet on Book Reviews. The matter was left in the hands of the editor of the JOURNAL OF CHEMICAL EDUCATION, who therefore submitted the following resolution, which was adopted by a unanimous vote:

"In view of the limitation of space in the JOURNAL OF CHEMICAL EDUCATION and the accumulation of unpublished book reviews, be it resolved that the Editor be authorized to publish such parts of this material as may be possible and that when publication is impossible, the publishers and reviewers be notified of our inability to do so."

Progress reports were made by the editor and the publisher.

There was an expression of appreciation to the Mack Printing Company for the support it has given the JOURNAL OF CHEMICAL EDUCATION.

The suggestion that a midwinter meeting of the Board be held, possibly in Pittsburgh, was given informal approval.

Plans were made for increasing the number of subscriptions to the JOURNAL.

PAUL H. FALL
Secretary

CONCERNING LANTERN SLIDES

WE HAVE an important and welcome announcement to make. Our readers have doubtless followed the recent developments in lantern slide technic. There is a strong feeling that the small, 2″ × 2″ slides are the hope of the future, and many of us are ready to go over to this form of slide if the change can be made inexpensively. This can now be done.

One of our associate editors, Professor H. N. Alyea, of Princeton University, has been actively working on this problem, largely in the interest of the Journal and the Division of Chemical Education He has prepared a Film Strip containing approximately 400 pictures and diagrams taken from the better known textbooks of general chemistry, as well as from this JOURNAL. He has arranged to have these copied and distributed *at cost* to any who are interested in starting a collection of slides. We have seen this strip and feel sure that any teacher will find from 200 to 300 pictures which he will want to use. The idea is that each will clip and mount those which are adapted to his own class work. Positive copies of the Film Strip are available for five dollars, the cost of printing. Cardboard slide-mounts can be had commercially at $7.20 for 300 and projectors for slides of this size are priced as low as $9.50, making a total price of a little more than $20 for a start on a library of modern slides. It is hoped that this will be but the first step in making slide material available at cost to chemistry teachers everywhere. Plans are under way to make industrial films, pictures of current chemical events, and colored slides on a variety of chemical topics available in the future.

Those interested are urged to send their orders for copies of this

first Film Strip to Dr. Alyea immediately. Those received before December 1 will be filled immediately; later ones will have to wait until a sufficient number have accumulated. He asks that remittance ($5.00) be made with the order, since there is no bookkeeping machinery to take care of the business.

The Journal is glad to give this project its blessing and all the publicity possible, since it is in no sense a commercial venture but a definite service in the interest of chemical education.

What's Been Going On

THE program of the Division of Chemical Education at the recent meeting in Detroit was unusually good. It began with a session devoted to a symposium on The Future of Chemistry as a Specialized Science in the High-School Curriculum, which was really continued from the last meeting in Cincinnati. A. J. Clark spoke on "Secondary School Preparation for College Chemistry," saying that a survey at Michigan State College showed an extraordinary state of unpreparedness on the part of students taking freshman chemistry. Ordinary, sixth-grade mathematics was one of the weakest points, and the best remedy suggested was a good combined physical science course in which students must really use their mathematical knowledge.

H. H. Metcalf told how to make high-school chemistry more "functional." Without sacrificing general principles and an appreciation of the scientific method it is possible to make the chemistry course more nearly meet the needs of modern social living, by means of exhibits, demonstrations, trips, local projects, movies, conferences. He suggested that in Detroit a chemistry course might well be built up entirely around the automobile industry.

I. C. Davis, guest speaker, discussed the question: "How much can the present chemistry courses contribute to the general education of boys and girls?" He submitted that the high-school curriculum is too unrelated, contains too much free elective. Among the desirable outcomes of education he listed: health, safety, recreation, a mature philosophy of life, intelligent consumership, orientation to work, conservation, mature personal relations, responsible social and political relations, scientific thinking. If chemistry as a subject is to serve any or all of these purposes it will have more work to do than ever before. Subject matter has no value *per se*, only its use. It may have to be reorganized to meet modern needs.

Ernestine M. J. Long, discussing "Elements and Safeguards of Scientific Thinking," maintained that present teaching methods do not develop scientific methods of thinking. There must be less emphasis on teacher and more on student activity. The subject matter of chemistry must become secondary to the scientific method.

S. R. Wilson, in a paper on "Science Fusion or Mental Confusion," maintained that the present tendency to scramble all the sciences together "is a psychoneurosis." The cure is to modify the courses in chemistry and physics to meet the demands of the non-college group.

There followed an excellent symposium on The Chemistry Curriculum of the First Two Years of College. These two sessions were organized by N. D. Cheronis,[1] who said, in introduction: "It is pretty generally agreed that the content, sequence, and methods used to teach those who are to specialize in the science of chemistry have on the whole produced satisfactory results, judging from the position of American chemistry. There is strong difference of opinion, however, as to the effectiveness of this same content and method for those who prepare for other professions, and particularly for those who wish to obtain a general education."

Most of those who participated in the discussion were of the opinion that some type of segregation of students is desirable. Some preferred three and others two groups, depending partly upon the size of the institution. It was generally agreed, however, that those who take chemistry as a part of general education should not have the same course as those who expect to use chemistry in later work. Where conditions permit, it seems highly desirable to give separate attention to the student of unusual ability.

Dr. Harker presented a very unusual paper on an "ultra-modern" course in general chemistry, which provoked a spirited discussion, as did his refusal to give the inductive method of reasoning any important place in scientific thinking.

There was general agreement that qualitative analysis can be introduced to great advantage during the last ten weeks of the second semester of general chemistry. For such a course, it is desirable for the student to have had high-school chemistry, and to organize the course in such a manner as to emphasize principles. It was maintained that such a course fits the programs of those who go into engineering.

It was pointed out that chemistry at the high-school level is changing, and this movement will undoubtedly affect the college curriculum as well. The desirability of liberalizing the chemistry curriculum in order that it may be more effective in general education was stressed.

There was a call for more statistical research in the field of chemical education at the college level, and it was suggested that this could only result if administrators give the same recognition to it as to specialized chemical research.

In quantitative analysis, the present tendency in courses seems to be to retain the old objectives of analytical skill and drill in stoichiometric calculations, and to add considerable emphasis on physical-chemical principles on which the laboratory operations are based.

R. D. Billinger counted the quantitative experiments in twenty-two recent laboratory manuals and found a great deal of difference in this regard.

William Rieman, 3rd, described an interesting laboratory experiment in which three different dyes are separated from each other in a mixed solution by adsorption and then each determined colorimetrically.

J. A. Southern discussed some of the principles upon which organic reagents must be chosen for inorganic analysis.

E. J. Bogan and E. P. Ingalls, Jr., showed an interesting color movie, illustrating the technic of gravimetric analysis.

H. E. Bent and C. L. French gave the results of their recent work on the well-known ferric thiocyanate reaction, showing that the colored complex should be represented by the formula $FeCNS^{++}$, neglecting hydration.

A. L. Elder gave an interesting account—with anecdotes—of his experiences in arranging science programs for adult radio listeners.

Ed. F. Degering showed how the principle of "Relative Electronegativity" can be used to advantage in the explanation of the reactions and properties of many organic substances.

T. H. Hazlehurst discussed the analogy between acid-base and oxidation-reduction reactions. (Complete paper in the October number of the JOURNAL.)

A paper by P. M. Glasoe explained how the periodic table can be used more effectively as a basis for instruction.

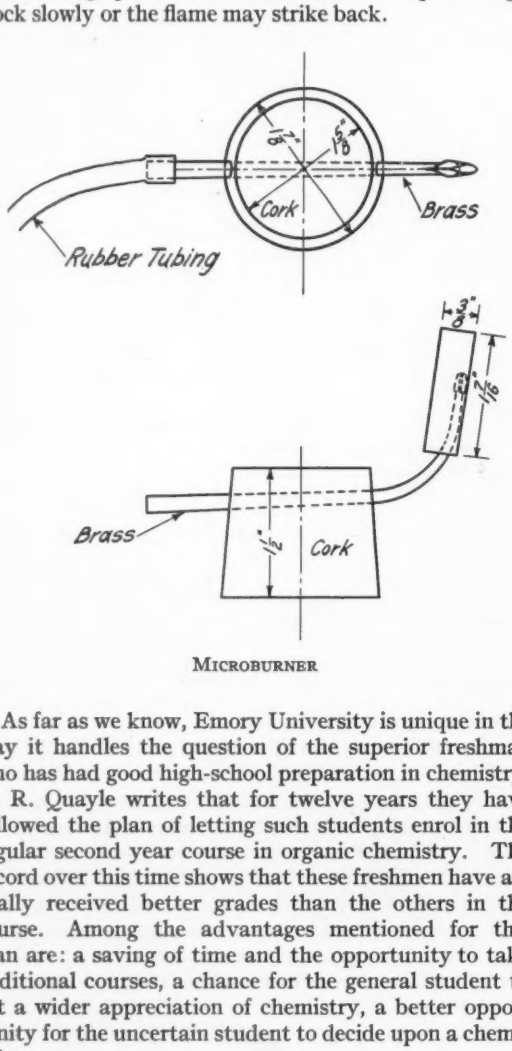
Irvin Lavine and O. T. Zimmerman showed how much of the unit operations equipment of a chemical engineering laboratory can be built in the departmental shop. They strongly recommended the use of students in the design and construction of the apparatus.

[1] Those members who requested a copy of "A Study of Quantitative Analysis," by C. G. Fawcett, from Dr. Cheronis, and who have not received one to date will kindly send a postcard with their name and address to: Dr. N. D. Cheronis, 5556 Ardmore Avenue, Chicago, Illinois.

Out of the Editor's Basket

ONE of our enthusiastic correspondents sends in the following: "*Thought for today:* Do you take your issue of the JOURNAL OF CHEMICAL EDUCATION home and share it with your family? Have it close to your bedside to look at when you wake or go to bed." Thanks, anyway, for not suggesting its use as a soporific!

• Charles Maresh, of the Calco Division of the American Cyanamid Company, sends us the accompanying drawing to show how an ordinary brass blowpipe can be used as an improvised microburner. The blowpipe is cut off short and mounted in a cork. A piece of the discarded end is pinched over the jet, holding it firmly but leaving space for air intake below. Open the gas cock slowly or the flame may strike back.



MICROBURNER

• As far as we know, Emory University is unique in the way it handles the question of the superior freshman who has had good high-school preparation in chemistry. O. R. Quayle writes that for twelve years they have followed the plan of letting such students enrol in the regular second year course in organic chemistry. The record over this time shows that these freshmen have actually received better grades than the others in the course. Among the advantages mentioned for this plan are: a saving of time and the opportunity to take additional courses, a chance for the general student to get a wider appreciation of chemistry, a better opportunity for the uncertain student to decide upon a chemical career.

• R. P. Seward, of Pennsylvania State College, had noted the statements in several textbooks to the effect that while sulfur dioxide is the product of the reaction of sulfuric acid on copper, the more active metals bring about a further reduction, with liberation of hydrogen sulfide. He studied the reaction of sulfuric acid on zinc and magnesium, at concentrations from 86 per cent to 98 per cent, and at temperatures from 175°C. to 200°C. There was no detectable H_2S, except a small trace in the case of zinc with the most dilute acid. Only small amounts of sulfur dioxide were obtained, in fact, this product being favored by high temperature. The formation of sulfur dioxide seemed also to be increased, catalytically perhaps, by the presence of impurities in the zinc. The principal reaction throughout was the liberation of hydrogen.

• R. E. Dunbar, of North Dakota Agricultural College, has made a survey of ten college textbooks of general chemistry as regards their "content of health material." Specifically, he has hunted to see how adequately they have presented the dangers associated with certain poisons and poisonous chemicals. The following is a list of poisonous substances in the *decreasing* order of the attention given them: carbon monoxide, mercuric chloride, auto exhaust, lead salts, arsenic compounds, illuminating gas, wood alcohol, stoves and heaters, phenol, kerosene, gasoline, carbon tetrachloride, bromides, lye, denatured alcohol, strychnine, lysol, sodium fluoride, nicotine, barbital and derivatives, paraldehyde, food poisoning. All books mentioned CO, none paraldehyde or food poisoning. The average score was about fifty per cent coverage. Since many poisons are organic and most general textbooks are largely inorganic he investigated ten college textbooks of organic chemistry and found the following list of poisons in decreasing order: wood alcohol, nicotine, phenol, strychnine, kerosene, lysol, gasoline, food poisoning, paraldehyde, carbon tetrachloride, barbital and derivatives, denatured alcohol. Eight out of ten mentioned wood alcohol and its dangers, two denatured alcohol. The average score showed fifty-six per cent coverage.

• The following description of an experiment was sent us by Ernest B. Wilson, of Jamaica, New York, to show some interesting things about evaporation and humidity:

Make two wet-bulb thermometers by wrapping cloth around the bulbs of ordinary thermometers. Put about 500 ml. of water in a $2^1/_2$-liter acid bottle, and an equal amount of concentrated H_2SO_4 in another. Let both stand for two to three hours, for the air in the one to become dry and the other saturated. Moisten the cloth on the bulbs of both thermometers (best with the water

in the one bottle) and fasten each thermometer in the neck of one of the bottles with a one-hole stopper, so that the bulb is about halfway down in the bottle. In ten or fifteen minutes there will be several degrees difference in temperature.

• The Commission on Teacher Education of the American Council on Education is extending its activities to include the preparation of college teachers. Dr. Ernest V. Hollis, of C. C. N. Y., has been chosen to direct the undertaking. During the fall semester Dr. Hollis expects to visit graduate schools whose Ph.D.'s predominantly go into college teaching and undergraduate colleges that are actively promoting the in-service growth of teachers. He invites interested college professors and administrative officers to write him (744 Jackson Place, Washington, D. C.) of their programs and plans and to indicate how he may be of service. It is not the Commission's plan to conduct intensive research but rather to act as a clearing house and stimulative agent for indigenous programs already underway. It clearly recognizes that the preparation of college teachers is a university-wide function.

• In many of our elementary laboratory courses magnesium ribbon is used in the determination of the "hydrogen equivalent." Often, to save time and trouble, the weight of the sample is calculated from its measured length, after having established an empirical relation. E. L. Gunn, of Lee Junior College, Goose Creek, Texas, wondered seriously whether the use of such "proportionate lengths" was sufficiently accurate, or whether the samples should be actually weighed. He weighed 14 meter-lengths of clean ribbon and cut them into 32 samples, which he measured accurately and also weighed on the balance. The average difference in actual weight from that calculated by length was 0.48 mg. When these samples were used in actual student experiments the results calculated independently from the weight and length of the ribbon were within the range of other experimental errors. (So go ahead and snip off the magnesium ribbon, if you prefer.)

RECENT BOOKS

PHYSICAL CHEMISTRY. *Earl C. H. Davies*, Ph.D., Professor of Physical Chemistry, West Virginia University. Second Edition. The Blakiston Company, Philadelphia, 1940. vii + 447 pp. 86 figs. 14.5 × 21.5 cm. $3.50.

This book was written to appeal to beginners, especially to that class of students who value physical chemistry for its cultural appeal rather than as an essential tool. The selection of subjects and manner of presentation should make it especially valuable for premedical physical chemistry. The mathematical aspects of the subject are not ignored but are given a distinctly elementary treatment. College sophomores should be quite capable of assimilating its contents.

The second edition is about twenty per cent more extensive than its predecessor. Although the number of chapters and titles are the same as before, each has been rewritten and enlarged. This is true particularly of the sections on proteins and enzymes and on isotopic applications and artificial radioactivity. In general, many new practical applications have been added. The treatment of colloids, pH, osmosis, catalysis, and hydrolysis is especially commendable. Glass electrode technic is discussed with unusual detail. Scattered throughout the text are numerous "illustrations" which can well serve as lecture demonstrations or laboratory experiments. This novelty and the general order of subject treatment has proved its value over a period of thirteen years. Text-interspersed experiments are supplemented by an appendix of twenty suggested laboratory experiments. Each chapter is terminated by a list of review and discussion questions and, in several cases, also by problems. The lecture and laboratory work represented can be covered in one semester, although more time can be used to advantage. There are many references to the recent literature. Eighty-two tables of useful data, many of them enlarged and modernized, and a table of logarithms considerably enhance the value of the book. The author's style is inspiring and the publisher's product very satisfactory.

The book is recommended to the attention of all teachers of introductory physical chemistry.

M. M. HARING

UNIVERSITY OF MARYLAND
COLLEGE PARK, MARYLAND

QUANTITATIVE ANALYSIS. *W. C. Pierce*, Associate Professor of Chemistry, University of Chicago, and *E. L. Haenisch*, Associate Professor of Chemistry, Villanova College. Second Edition. John Wiley and Sons, Inc., New York City, 1940. xv + 462 pp. 35 figs. 15 × 23 cm. $3.00.

This second edition of a book that has enjoyed considerable popularity has introduced no fundamental change in content over the first edition. Examination of the table of contents shows a new chapter (V) with the title, "Preparation of Sample for Analysis," which includes a brief introduction to the important topic of sampling. In the last chapter of the book a brief discussion of certain special methods of analysis has been replaced by a listing of the standard, analyzed samples put out by the National Bureau of Standards. In the body of the text newer methods are occasionally introduced, as may be seen in the use of sulfamic acid as a primary standard in neutralization titrations, the adoption of the Fowler and Bright manipulation in the standardization of $KMnO_4$ by $Na_2C_2O_4$, and in the use of As_2O_3 as a primary standard for $KMnO_4$ in the presence of an iodine catalyst.

There is considerable reorganization of material in several of the chapters, presumably in the interest of improved pedagogy. In many cases the discussion has been amplified, directions made more specific, and center headings added or improved to make the text more readable. Additional problems have been inserted at the end of many of the chapters, giving a wider choice of assignments.

The chief deficiencies for a book of this character are (1) failure to recommend the electric muffle for gravimetric ignitions, and (2) failure to indicate the importance of outflow time in the use of a buret or transfer pipet, since the tolerances specified by the Bureau of Standards include outflow times as well as volumes delivered.

The book is well written and well printed and will deservedly continue to be widely used as a textbook in colleges for the one-semester, heavy courses, or the two-semester, lighter course in quantitative analysis.

R. K. MCALPINE

UNIVERSITY OF MICHIGAN
ANN ARBOR, MICHIGAN

A COURSE IN GENERAL CHEMISTRY. *William C. Bray* and *Wendell M. Latimer*, Professors of Chemistry in the University of California. Third Edition. The Macmillan Co., New York City, 1940. xi + 206 pp. 2 figs. 14 × 21 cm. $1.60.

This work consists of a series of thirty-four laboratory assignments. Each experiment is accompanied by a number of questions and problems, designed to stimulate discussion by the student of the underlying theories and to train him in scientific thinking through application of the principles involved to new problems.

A preliminary chapter is given entitled, "Outline of the Course," in which the authors discuss the objectives of the course and present a "Weekly Schedule" which indicates the lecture and reading topics as well as the laboratory assignments to be covered during each of the thirty-two weeks of the course.

The thirty-four laboratory assignments are divided into four sections under the following general headings.

Section I. Weight Relations in Chemical Reactions. (Seven Assignments.)

Section II. Ionic Theory. Rapid Reversible Reactions and Equilibrium. (Twelve Assignments.)

Section III. Introduction to the Systematic Study of Reactions of Ions in Aqueous Solutions. (Twelve Assignments.)

Section IV. Qualitative Analysis. (Three Assignments.)

An appendix gives special laboratory directions and directions for preparation of reagents.

Teachers of inorganic chemistry and qualitative analysis will be interested in this book, and in certain situations with small classes of superior students the whole course might be adopted very profitably.

ARTHUR J. CLARK

MICHIGAN STATE COLLEGE
EAST LANSING, MICHIGAN

MODERN COSMETICOLOGY. *Ralph G. Harry.* Chemical Publishing Co., Inc., New York City, 1940. xiii + 288 pp. 10 figs. 15 × 22.5 cm. $5.00.

This new book on the compounding of cosmetics is a valuable addition to the rapidly increasing literature in this field because it gives much more information on scientific background and practical application than is customary in books on raw materials and recipes.

In thirty-five chapters, the author covers the histology of the skin, hair, and nails, and every type of cosmetic preparation in general use. Special attention is given to preservatives, the problems of absorption by the skin, allergy and dermatitis, and the use of organotherapeutic substances—vitamins and hormones. The text is well documented throughout, this interpolation taking the place of the bibliography at the back. It is well indexed, and there are several excellent photomicrographs to illustrate important points.

The author, a consulting chemist and public analyst of London, believes that anyone who wishes to keep abreast of the steady interest in cosmetics should also keep up with all the new products offered by the manufacturers of raw materials. His recipes show consistent use of many of these and he guarantees that all have been well tested. Therein lies the disadvantage of the book—in listing recipes, one after another, with two to several commercial products identified only by their proprietary trade names. There are some explanatory paragraphs about the general nature of some of these compounds, but this is not sufficient for the enterprising scientific investigator.

MODERN COSMETICOLOGY should be a useful reference book for teachers and investigators who want to know what is in cosmetic preparations and why; but it would have been greatly improved by the addition of an appendix, giving the chemical names of these worthy trade products, or at least the names of American trade products which can be substituted for them.

FLORENCE E. WALL

685 MADISON AVENUE
NEW YORK CITY

FRUIT PECTINS: THEIR CHEMICAL BEHAVIOUR AND JELLYING PROPERTIES. *C. L. Hinton*, F.I.C. Chemical Publishing Co., Inc., New York City, 1940. viii + 96 pp. 13 figs. 13.5 × 21.5 cm. $1.75.

This book is Food Investigation Special Report No. 48 published by the Department of Scientific and Industrial Research (Great Britain).

The experimental work and discussions cover the following topics—a brief survey of the constitution of pectins; the characterization of pectins by acetone precipitation, calcium pectate and pectic acid yields; the measurement of jelly-forming capacity; methods of preparation of pectin specimens from various fruits and their chemical properties; the effects of heating, of alkalies, of acids, and of salts of pectins; changes produced by the action of pectase and factors modifying the jelly-forming properties of pectins during their extraction from fruits.

This report is written in the excellent manner which is characteristic of the reports published by the Food Investigation Board and will be found valuable to those who are interested in pectins from the scientific point of view, as well as to those who are concerned with the practical problems of jam and jelly manufacture.

ARTHUR W. THOMAS

COLUMBIA UNIVERSITY
NEW YORK CITY

SULPHATED OILS AND ALLIED PRODUCTS: THEIR CHEMISTRY AND ANALYSIS. *D. Burton* and *G. F. Robertshaw.* Chemical Publishing Company, New York City, 1940. iv + 163 pp. 13.5 × 22 cm. $5.00.

This book is an excellent guide to the analyses of sulfated oils, sulfonic acids, sulfated fatty alcohols, and the like. A number of analytical methods are presented in considerable detail. The methods are described in a simple, clear manner, which should be readily followed with a critical review in order to avoid drawing unwarrantable conclusions as to the products present in the mixture. A simple historical review is given which has some value from a reference standpoint.

The book should be quite useful to those engaged in this important field of sulfated oils—which are playing an increasing role in industry.

GUSTAV EGLOFF

UNIVERSAL OIL PRODUCTS COMPANY
RIVERSIDE, ILLINOIS

ADVANCED READINGS IN CHEMICAL AND TECHNICAL GERMAN. Selected and edited by *J. T. Fotos* and *R. N. Shreve.* John Wiley and Sons, Inc., New York City, 1940. xiii + 304 pp. 14 × 20 cm. $2.50.

This is the fourth and last member of the Fotos-Bray-Shreve, or Purdue University, series in chemical and technical German. The first (GERMAN GRAMMAR FOR CHEMISTS AND OTHER SCIENCE STUDENTS) and the third (INTERMEDIATE READINGS IN CHEMICAL AND TECHNICAL GERMAN) have already appeared; the second (INTRODUCTORY READINGS IN CHEMICAL AND TECHNICAL GERMAN) is in press. The present work can, however, be used independently by persons who already have some ability to read ordinary German.

The readings are taken from the following sources: Inorganic, Gmelin; organic, Beilstein, Meyer and Jacobson, Houben; technical, Ullmann, Oberhoffer; metallography, Guertler. Each page is accompanied by a vocabulary and notes. Other features of the book are a helpful list of the main reading difficulties met with in reading scientific German; a list of 2250 German words in the order of frequency in which they occur in the readings; a complete vocabulary; symbols and abbreviations used in the book, with their meanings; a list of strong and irregular verbs, with their principal parts; and abbreviations and titles of periodicals cited in the readings.

The ADVANCED READINGS seem well selected and edited and are unusually fully implemented. They will undoubtedly serve their purpose well.

AUSTIN M. PATTERSON

ANTIOCH COLLEGE
YELLOW SPRINGS, OHIO

LABORATORY MANUAL FOR GENERAL COLLEGE CHEMISTRY. *J. A. Babor* and *A. Lehrman*, College of the City of New York. Thomas Y. Crowell Co., New York City, 1940. 292 pp., Wiro-o binding. 46 figs. 21.5 × 28 cm. $1.75.

EXPERIMENTAL GENERAL CHEMISTRY. *J. W. Neckers, T. W. Abbott* and *K. A. Van Lente*, Illinois State Normal University. Thomas Y. Crowell Co., New York City, 1940. 282 pp., Wire-o binding. 22 figs. 21.5 × 28 cm. $1.75.

LABORATORY MANUAL TO ACCOMPANY FUNDAMENTALS OF CHEMISTRY AND APPLICATIONS. *C. A. Francis* and *E. C. Morse*, Teachers College, Columbia University. The Macmillan Company, New York City, 1940. 152 loose pp., punched for cover, in an envelope. 19 figs. 21.5 × 28 cm. $1.00.

EXPERIMENTAL CHEMISTRY FOR COLLEGES. *J. A. Harris* and *W. Ure*, University of British Columbia. McGraw-Hill Book Co., New York City, 1940. 123 perforated pp., punched for cover, paper bound. 21 figs. 19 × 26.5 cm. $1.25.

LABORATORY MANUAL OF GENERAL COLLEGE CHEMISTRY. *L. B. Richardson* and *A. J. Scarlett*, Dartmouth College. Revised Edition. Henry Holt and Co., New York City, 1940. 243 perforated pp., spiral wire binding. 23 figs. 21 × 28 cm. $1.40.

Any of these manuals would serve satisfactorily to guide the freshman through the usual first year's laboratory work in chemistry. While some are designed to accompany specific textbooks, they are nevertheless essentially independent and could be used with any standard textbook. A casual inspection of these and comparable laboratory manuals fails to disclose any tendency toward an increased use of the inductive laboratory approach to chemistry. The difficulties presented by mass education with the resulting large laboratory sections, frequently taught by inexperienced graduate assistants, evidently are best met by such carefully planned outlines as these. Initiative and inquisitiveness, however, are not encouraged, and because of the routine character of the work, it is to be expected that all too often able students will reject rather than be attracted to careers in natural science.

LAURENCE S. FOSTER

BROWN UNIVERSITY
PROVIDENCE, RHODE ISLAND

NATURE OF THE CHEMICAL BOND. *Linus Pauling*, Professor of Chemistry, California Institute of Technology. Second Edition, revised. Cornell University Press, Ithaca, New York, 1940. xvi + 440 pp. 88 figs. 47 tables. 15 × 23 cm. $4.50.

Designed as an introduction to modern structural chemistry, this book presents the essential criteria of molecular and crystal structure with a minimum of mathematics. Nevertheless, because of the necessary condensation of elementary discussion the beginner will find it necessary to fill in his background from other sources.

Naturally, the concept of resonance, developed largely by the author and his co-workers, has a dominant place. It is the unifying theme of modern structural chemistry as presented by Pauling.

Those who are familiar with Sidgwick's, "The Covalent Link in Chemistry," will find in Pauling's book an entirely different approach to covalent and ionic bonds. Sidgwick develops the hypothesis that covalent and ionic bonds are fundamentally distinct; Pauling develops the concept of a mixed bond on a sliding scale, a bond which is partially covalent and partially ionic in character, its behavior being determined largely by the predominant character.

In the judgment of the reviewer, this book marks a most significant modern advance in the field of molecular structure, an advance which will lead soon, let us hope, to a far more quantitative approach. No teacher of chemistry can afford to be unaware of the progress being made in this field; no book on the subject presents a clearer, more unified panorama of the field.

SIDNEY J. FRENCH

COLGATE UNIVERSITY
HAMILTON, NEW YORK

PHYSICAL ORGANIC CHEMISTRY. *L. P. Hammett*, Columbia University. McGraw-Hill Company, New York City, 1940. vi + 404 pp. 14 × 21 cm. $4.00.

The many admirers of Professor Hammett's scholarly researches in the field of kinetics of organic reactions in solution will welcome the appearance of this volume in which he surveys the rapidly moving developments in this field and in closely related subjects. To those not familiar with the original contributions of the author the sub-title, "Reaction Rates, Equilibria, and Mechanisms," will indicate more clearly the scope of the book.

The approach is distinctly physical. The physicist, or the physical chemist, enters by the familiar path of the quantization of the hydrogen atom, and this leads naturally into a discussion of modern valence theory. The uninitiated need not be deterred by so austere a beginning; the mathematical expressions are introduced merely to show in a general sort of way how the theorists tackle problems of molecular structure, and the discussion is eminently successful in leading simply and directly to the important concept of resonance. The quantum mechanical picture of the structure of molecules and ions underlies the whole of the interpretation of reaction rates and equilibria which is to follow.

Professor Hammett's well-conceived, well-executed, and well-printed book will be on the reading list for every graduate student of organic chemistry.

WELDON G. BROWN

THE UNIVERSITY OF CHICAGO
CHICAGO, ILLINOIS

COLLOID CHEMISTRY (A TEXTBOOK). *Harry Boyer Weiser*, Professor of Chemistry, The Rice Institute. John Wiley and Sons, Inc., New York City, 1939. viii + 428 pp. 103 figs. 15 × 23 cm. $4.00.

This is a textbook of colloid chemistry written for college students specializing in chemistry or chemical engineering, who have completed an introductory course in physical chemistry. Colloid chemistry has grown so rapidly during the past quarter of a century that the subject no longer can be covered adequately in general chemistry or in an introductory course in physical chemistry. For this reason most educational institutions have found it highly desirable to offer a separate course on the theory and applications of colloidal behavior. This book was designed for such a course and with a threefold purpose: ". . . to acquaint the student with the foundations of colloid chemistry and with the role that the classical experiments have played in the development of the modern theories and applications of the subject; to formulate systematically and to correlate critically the theories underlying colloid chemical behavior; and to illustrate the widely diversified applications of the principles of colloid chemistry in such fields as the industrial arts, agriculture, and biology."

This book will be valuable not only as a textbook for a comprehensive course on the theory and applications of colloidal behavior, but also as a reference book for those who wish to correlate and extend their scientific knowledge. It is well planned, and the proofreader has done a good job.

JOHN H. YOE

UNIVERSITY OF VIRGINIA
UNIVERSITY, VIRGINIA

ORGANIC SYNTHESES, Volume XX. *Charles F. H. Allen*, Editor-in-Chief. John Wiley and Sons, Inc., New York City, 1940. v + 113 pp. 6 figs. 15 × 23 cm. $1.75.

This current volume of the series, "An Annual Publication of Satisfactory Methods for the Preparation of Organic Chemicals," contains directions for thirty-nine new preparations. An index comprising material from the volume is also given.

The utility and reliability of this series in preparative organic chemistry is generally so well appreciated that no further comment is deemed necessary.

MAX F. ROY

BROWN UNIVERSITY
PROVIDENCE, RHODE ISLAND

THE TOOLS OF THE CHEMIST, Their Ancestry and American Evolution. *E. Child.* Reinhold Publishing Corporation, New York City, 1940. 220 pp. 104 figs. 14.5 × 22 cm. $3.50.

The present book—being an account of the history of the American chemical apparatus industry, with a sufficient discussion of its beginnings and background in Europe and of the American inventors and men of science who devised or made use of the equipment—constitutes an important contribution to the more general history of American chemistry. It is easy and interesting to read, stimulating to a further inquiry into the history of chemistry, and attractively illustrated with one hundred four pictures, two of them full-page color plates and many of them portraits of chemists or pictures of historic apparatus.

A foreword (pp. 5–8) by C. A. Browne is followed by Part I (pp. 17–67), "People and Events in American Chemistry," by Part II (pp. 71–170), "Ancestry and Development of American Chemical Laboratory Apparatus," subdivided into sections (1) "Balances," (2) "Glassware," (3) "Porcelain Ware," (4) "Silica Ware," (5) "Filter Paper," (6) "Heating Apparatus," (7) "Metal Laboratory Ware," (8) "Platinum," (9) "Aluminum," (10) "Rubber Ware," and (11) "Optical Ware," by Part III (pp. 173–206), "Distributors of Laboratory Apparatus," and by an Index (pp. 207–20).

The book is the result of what must have been slow and difficult research, the setting down of a history much of which is not to be found in the printed records but was only to be gleaned from conversations and from the records of business houses. It contains information which is not to be found elsewhere, and the information is made easily available by an excellent index. It is a book which ought to find its place in libraries which are interested in the history of chemistry, in chemical industry, in the history of American business and manufacturing, and, we believe also, in libraries which are interested in the popularization of science and technology.

TENNEY L. DAVIS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS

REFERENCE BOOK OF INORGANIC CHEMISTRY. *W. M. Latimer*, Ph.D., and *J. H. Hildebrand*, Ph.D., University of California. Revised Edition. The Macmillan Co., New York City, 1940. xii + 563 pp. 14 × 21 cm. $4.00.

This revised edition, which has appeared after a ten-year interval, is a thorough modernization of a well-known book.

As in the first edition the contents comprise twenty-two chapters covering the descriptive chemistry of the elements, a glossary, and nineteen appendices. The arrangement is the same as in the first edition and the chapter headings are unchanged, except that the chemistry of rhenium is included in the chapter on manganese. In the appendices, "Structure of Molecules and Ions" takes the place of "Borax Bead Tests" in Appendix Seven; "Acid Ionization Constants" have been included along with "Solubility Products" in Appendix Eleven; and "Covalent Bond Energies and Atomic Radii" have been substituted for the Table of Coefficients of Linear Expansion in Appendix Sixteen. The inclusion of new material and the use of a more readable type have increased the size of the volume from four hundred forty-two to five hundred sixty-three pages.

The revision is unusually complete with regard to thermodynamical data, such as oxidation-reduction potentials, equilibrium constants, and free energy values. Much discrimination has been exercised in assembling these data. New discoveries in the general field of chemical facts have been brought up-to-date. The chapter on the radioactive elements has been largely rewritten to include the discoveries over the past ten years in nuclear physics. The selection of material, a difficult task in the preparation of a one-volume reference book, has been given careful consideration, and data are available for dealing with most of the problems arising in inorganic chemistry.

Those acquainted with the first edition will find the usefulness of the book greatly increased.

G. C. CHANDLEE

THE PENNSYLVANIA STATE COLLEGE
STATE COLLEGE, PENNSYLVANIA

THE KINETICS OF CHEMICAL CHANGE, *C. N. Hinshelwood*, University of Oxford. Oxford University Press, Oxford at the Clarendon Press, England, 1940. vii + 274 pp. 35 figs. 15 × 24 cm.

THE KINETICS OF CHEMICAL CHANGE is completely rewritten since earlier editions and has also been shortened. The point of view taken all through the book is essentially the one to which the author has contributed so much. The author has attempted to outline the general theory of chemical reactions and to this end gives a good elementary treatment of statistical mechanics, a treatment of activation energies both from the classical standpoint of potential surfaces, and a treatment of the collision theory of which he has been an exponent. No attempt seems to have been made to cover a large number of reactions but rather to take certain specific examples and show the applications of the theory to them. As will always be true in this field, objections may be raised in some instances to mechanisms proposed, but on the whole the author seems to have dealt with data in an impartial manner. The book does contain the method of calculating activation energies as developed by Polanyi, Eyring, and others, but contains no discussion of the more recent point of view concerning the steric factor as developed particularly by Eyring. Therefore the treatment in a sense may be called classical and is based on the old collision picture to a large extent. In some instances a more critical evaluation of the data might be called for, but on the whole the book is worth reading by students of the subject, and the early chapters would serve as a useful treatment to advanced students who wished to make a beginning in it.

W. ALBERT NOYES, JR.

THE UNIVERSITY OF ROCHESTER
ROCHESTER, NEW YORK

HANDBOOK OF CHEMICAL MICROSCOPY, Volume II, Chemical Methods and Inorganic Qualitative Analysis. *E. M. Chamot* and *C. W. Mason*, Cornell University. Second Edition. John Wiley and Sons, Inc., New York City, 1940. xii + 438 pp. 233 figs. 15 × 23 cm. $5.00.

While no significant changes in technic or apparatus appear to have been made in the nine years since the appearance of the first edition, new microchemical tests have been discovered. The second edition has been completely reset and enlarged to include these newer tests.

Some changes in order or arrangement were made in certain sections, though in general the plan of the original volume has been maintained. An appendix on the preparation of reagents and a short general bibliography and subject index conclude this book. Nearly all tests are illustrated with excellent photomicrographs.

This handbook will be of value to analytical chemists and to research workers in chemistry, mineralogy, and allied fields. Every laboratory possessing a polarizing microscope, and this should include every chemical laboratory, will have need of this volume. It is an admirable text and can be recommended for specialized courses in chemical microscopy.

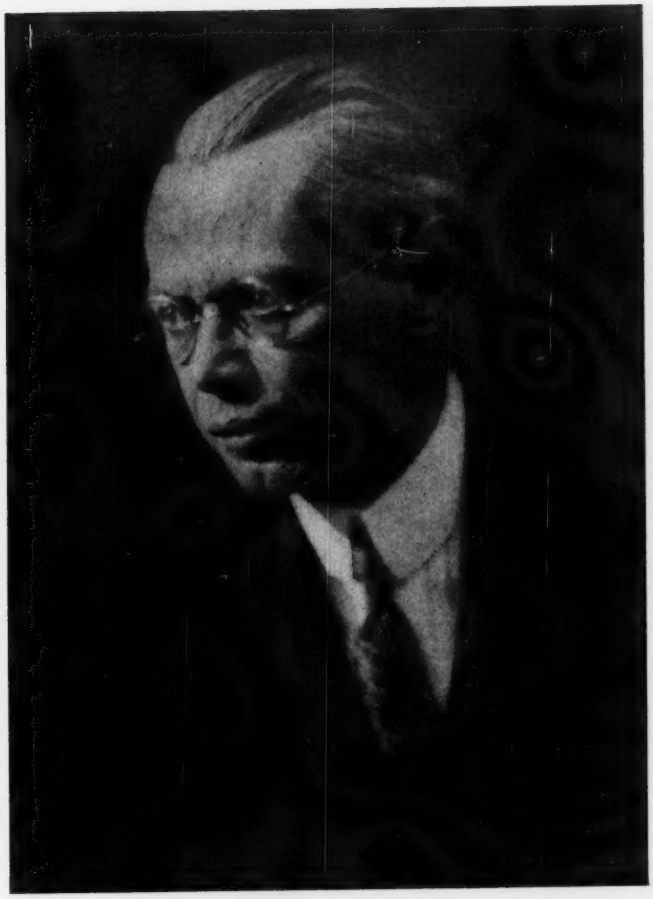
F. J. PETTIJOHN

THE UNIVERSITY OF CHICAGO
CHICAGO, ILLINOIS

A NEW DICTIONARY OF CHEMISTRY. *Stephen Miall*, LL.D., B.Sc., Editor. Longmans, Green and Co., New York City, 1940. xv + 575 pp. 15 × 23 cm. $15.00.

As a handy, concise book of reference, the NEW DICTIONARY OF CHEMISTRY seems to answer a need experienced by all those interested in the historical and technical developments of chemistry and the allied sciences. Not only a dictionary of chemical processes and materials, the dictionary contains biographical material on notable chemists.

THE CHEMISTS' YEAR BOOK. Founded by *F. W. Atack*, edited by *E. Hope*. The 1940 Revised Edition. Chemical Publishing Company, Inc., New York City, 1940. 1257 pp. 9.5 × 15 cm. $6.00.



Otto Hönigschmid
(1878–)

Contributed by Ralph E. Oesper, University of Cincinnati

(For biographical sketch of Otto Hönigschmid, see page 562.)

Editor's Outlook

HOW curiously the wheels of fate repeat themselves—or else go into reverse! When we first read the article on "Chemical Prefaces," which appears in this issue, we had a glimmering recollection of one we read long ago. So we dug into the library and dusted off Plotnikow's "Lehrbuch der Photochemie" (1920) to refresh our memory. A more pathetic, but at the same time violent description of the conditions under which a book was written would be hard to find. This Russian author, after a brief reference to his earlier writings, tells how he had long planned a comprehensive handbook of photochemistry and how he at last came to the point of starting work on it. But the world was troublous and men's emotions and ambitions were erupting in turbulent fashion at about that time, so that the author's difficulties were many. But let's hear his own description of them, translated, perhaps feebly, from the vigorous German:

"The writing of this work and the organization of the material which I had collected for many years was begun in the summer of 1917, at my country place, "Black Sea." All around there raged the unrestrained and destructive fury of the Russian mob. Day after day I had to stand by helplessly and watch the henchmen of Kerenski and Tschernoff plunder and destroy the estate which I had built up with so much care, expense, and labor, until finally, in November, it was leveled to the ground. My library was used for cigarettes. We found refuge in a few miserable rooms in Moscow, where, amidst the continuous gunfire of the Bolshevik revolution and the subsequent reign of terror and hunger, the work had to be carried on. It was a laborious and sorrowful struggle. My scientific library, painfully collected and cherished for so many years, melted away, exchanged book by book for the scant daily bread, to save my wife and child from the menace of starvation. In the first days of the revolution I had been relieved of my professorship at the University by the dictatorial, lawless, and violent prejudice of the minister of education, Manuiloff, who could only tolerate men of his own political leanings. The first Russian photochemical laboratory, which I had founded with so much care, and partly with my own money was eventually liquidated. As the food question became more acute, and all sources at last failed, we fled for our lives, in the autumn of 1918, out of this social paradise to our relatives in the Ukraine. In Charkoff the mathematical part of this work was completed. But the Bolshevik waves of hunger and blood pressed closer and closer to the rich and sunny Ukraine, threatening to engulf it and cut me off again from the civilized world. In the name of the new social justice I was reduced to the state of a wandering beggar, while others, physically stronger than I, enriched themselves at my expense. I was even deprived of my scientific home. Whether fate would ever have granted me another, where I could carry on my research in peace, is questionable, for, I am sorry to say, party and national politics and prejudice play a more important role among scientists than elsewhere. My position was precarious. Then came the long awaited help from Germany. Thanks to the opportune intervention of German scientists and industrialists I was permitted to come to Germany, and Christmas of 1918 found me in the company of my friends and protectors in Leipzig. Unfortunately, my wife and child could not accompany me but had to remain in Charkoff, and due to the shortsighted and naive politics of the Entente I was unable to get news to them for two years. On German soil, so fruitful for all kinds of scientific endeavor, I was able to bring my previous work to conclusion."

Keeping that last sentence clearly in mind, let us tear twenty times twelve pages off the calendar of time. A new revolution has leached the nourishment from the "fruitful soil," which has turned bitter and alkaline. And the people of the land, once sympathetic and hospitable, seem also to have become bitter and intolerant. Another scientist and author has been "deprived of his scientific home." This time it is Fritz Feigl, who writes, somewhat more restrainedly, in the preface to the second edition of his "Qualitative Analysis by Spot Tests" (1939):

"Owing to the annexation of Austria by the German Reich I lost, as well as many other scientists, my position as a Professor at the Vienna University. At this time the University of St. Andrews in Scotland offered me an opportunity to continue my researches in the Chemical Department of that University and was ready to give all necessary help. Though I did not make use of their generous offer, it has helped me to maintain my faith in the community of science, in a time of deepest depression. I therefore dedicate this book to my honoured colleagues of the Chemical Department of the University of St. Andrews, Scotland, as a sign of my sincerest gratitude for their comradeship and liberal attitude."

All this is not meant as an indictment of anyone in particular, but rather as an indication that there is, after all, an international "community of science" which is more or less of a going concern in a stalled world. We don't share Plotnikow's opinion of political prejudice among scientists.

Bergman, Klaproth, Vauquelin, Wollaston[1]

ELSIE GRUEBER FERGUSON Newcomb College, New Orleans, Louisiana[2]

THE chemists whose lives and work are very briefly discussed in this paper are men whose names are not as familiar as are those of Lavoisier, Gay-Lussac, Proust, Scheele, Berzelius, Cavendish, Priestley, or Dalton, contemporaries of our characters, but whose importance in connection with the development of analytical chemistry is unquestioned. Bergman was the first of that great trio of which Sweden is so justly proud, Klaproth was without a rival the greatest chemist in Germany of his time and was everywhere respected, Vauquelin was the greatest analytical chemist in France at the turn of the century (1800), and Wollaston held the same position in England.

In order to evaluate their contributions properly it is necessary that we think of chemistry as it had developed up to about 1700. Since Mr. Hooke's advanced ideas were not generally known, the phlogiston theory was gaining supporters. With Boyle, chemists thought of fire as a "weighable element," though if they read Boyle further they found that he defined an element as a substance incapable of further chemical decomposition by fire or other means. Of the ninety-two elements known to us today exactly one dozen (antimony, arsenic, carbon, copper, gold, iron, lead, mercury, phosphorus, silver, sulfur, tin) were known in 1700. Chemical reaction was explained on the basis of chemical "affinity," a term employed by Hooke and defined by Thomas Thomson as "the power by which the ultimate particles of bodies are made to unite together and are kept united."[3] It was commonly believed that only those substances possessed affinity for each other which had something in common with each other. Not until about 1800 did Newton's term "attraction" find common usage. The term attraction was up to that time confined to cases of forces acting at sensible distances, such as between planets and stars, and was not applied to forces acting between minute particles of matter. Oxygen was unknown, the fundamental laws of weight were unknown. Seldom was attention paid to the balance and even when it was considered, the results as obtained were misleading. Thus Homberg, friend and student of Otto von Guericke and later a colleague of Lemery, found in the late seventeenth century that equal amounts of all acids change the weights of various samples of tartrates by the same amount.

The analytical chemistry of the time was of interest to the mineralogist, the pharmacist, and to a few industries. There were, of course, no formal courses in analytical chemistry. Some of the methods used then are familiar to us now—they included the processes of filtration, sublimation, crystallization, distillation. Steam distillations were carried out in wooden vessels since the glass vessels were thick, crude, and not very strong. Crucibles were made of metals or, more frequently, glazed earthenware. Porcelain crucibles were unknown before 1778. Oil lamps were the source of high temperatures, but not until 1773 were several of these lamps together used to heat an oven. The microscope had been used by Duclas in 1670 to distinguish between crystals of table salt and gypsum in mineral waters. Duhamel had, in 1700, not yet distinguished soda from potash. Analysis in the dry way and analysis in the wet way were both in use, but it was not assumed that these two methods should yield similar results.

From Weeks's "Discovery of the Elements"

TORBERN BERGMAN, 1735–1784

What did Bergman, Klaproth, Vauquelin, and Wollaston do to further the growth and development of chemistry? One of these was the son of a tax collector, another of a merchant, a third of a serf, and the last the son of a clergyman. One was very poor and one came from a family which had enjoyed education, culture, and wealth for generations. One was not only discouraged from entering a scientific career but was forbidden to do so; the others were encouraged. Two were married, two not. Yet these four men coming from four different countries with widely differing backgrounds are considered the four greatest analysts of the the eighteenth century. We shall consider briefly the life and work of each of these four men.

[1] Delivered before a seminar in the History of Chemistry at Tulane University, New Orleans, Louisiana, April 27, 1939.

[2] Present address: 3432 North Washington Road, Fort Wayne, Indiana.

[3] THOMSON, "A system of chemistry," 5th London ed., Abraham Small, Philadelphia, Pa., 1818, Vol. III, p. 9.

Torbern Bergman was born on March 20, 1735 (one hundred years after Hooke, four years after Cavendish, two years after Priestley) in Catherinberg, West Gothland. His mother was the daughter of a merchant, his father a receiver of revenues—a post of uncertain duration, depending upon the political swing of the diet in power. In order for his son to be in a remunerative as well as a permanent position, he urged him to study law or divinity, for which purpose he was sent to the University of Upsala at the age of seventeen and placed under the care of a relative who was a "magister docens" at Upsala. Bergman had already displayed remarkable interest and ability in physics and mathematics at the gymnasium in Skara, so that the relative was charged with the duty of weaning him away from these interests. He was therefore found studying law whenever the "magister docens" made his rounds, but at the end of the call Bergman rapidly found his favorite books. In his attempt to do well in law to please his family, and well in mathematics and physics to please himself, he neglected to get exercise or diversion. After two years his concentrated efforts and lack of sleep (a maximum of five hours a night was all that he allowed himself) told on his health and he was obliged to leave the university.

At Upsala at that time Linnaeus was kindling a great interest in natural sciences in all the students. Bergman was no exception. While he regained his strength at home, he took long walks and collected many plants and insects, some not listed by Linnaeus. His health restored, he returned to Upsala, this time with full permission to study his favorite subjects. His first paper was published in the *Memoirs* of the Stockholm Academy in 1756 and concerned the ovum of a leech which contained a dozen young animals. The paper was autographed by Linnaeus who signed it "Vidi et obstupui," since he had not believed what Bergman had recorded until he saw it himself. Bergman then published other papers on the history of the insects that attack fruit trees, the means of recognizing them from their larvae, and on the methods of guarding against these insects. He proudly related that in one summer in one garden seven million destructive insects had been destroyed by his method.

In 1758 Bergman got his master's degree, his dissertation being on a mathematical problem in astronomy. He was made "magister docens" in natural philosophy at the University of Upsala, and in 1761 became adjunct professor in mathematics and in physics. This post he held until 1767. During this time he published papers in the *Memoirs* of the Stockholm Academy on the rainbow, twilight, the aurora borealis, and the electrical phenomena of iceland spar. He was one of the first to view the transit of Venus over the sun in 1761.

Professor of chemistry at Upsala at that time was Wallerius. He was retired in 1767 and intended that one of his relatives should be his successor. It was a surprise to nearly everyone that Bergman applied for this position in chemistry, since his interests seemed to be entirely in other fields. To prove his qualifications he immediately published two dissertations on the manufacture of alum. Wallerius formed a party to oppose Bergman and was joined in this by all who, according to Thomas Thomson, "despaired of equalling his reputation and industry."[4] Thanks to the personal plea of Gustavus III of Sweden, whom a friend of Bergman had influenced, Bergman was appointed Wallerius' successor.

His excellent background in mathematics, physics, and natural science proved most helpful to him in his position, enabling him to see more clearly some of the weaknesses of the science of chemistry of his time. He was convinced of the need of a new nomenclature and of the necessity of establishing chemistry on an experimental basis. Bergman's lectures were described as exceedingly valuable. If the sign of a good teacher is the number of good students he produces, Bergman passes the test well, for Gahn, Hjelm, Gadolin, and the Elhuyars all called him "professor." That Bergman was a leader among his colleagues is shown by his selection as Rector of the University, an honor bestowed soon after his appointment to the Chair of Chemistry, and one of the greatest of the many honors which came to him. Since the University of Upsala owned a tremendously large estate which the faculty managed under the guidance of the rector, a successful rector needed to be an excellent business manager, a person of foresight enough to keep a safe balance between good teachers and good business managers on his staff, and, as always, a person of tact and wisdom in dealing with people. The period in the life of the University of Upsala, when Bergman was at the helm, is remarkable for the smoothness with which the affairs of the University were conducted.

His reputation rapidly spread abroad both as a chemist and as an administrator. Honorary membership in many foreign scientific societies attested to the importance of his contributions; these came freely in spite of his double duty as administrator and professor, which was steadily undermining his strength. In 1776 Frederick the Great of Prussia invited him to come to the Berlin Academy of Sciences at a greatly increased salary with greatly reduced duties. For the sake of his health Bergman was tempted to accept. Hearing that his leaving would pain the King of Sweden who had earlier befriended him, Bergman declined the offer and begged the King not to spoil his sacrifice by raising his salary—a plea to which Gustavus III lent no ear.

In 1771 Bergman married Margaret Catherine Trast, a widow, daughter of a clergyman near Upsala. They had two sons, both of whom died in infancy. Bergman himself never enjoyed good health after his first two years of intensive work at Upsala. From 1769 on his health failed constantly, from 1780 on very rapidly. It is not surprising, therefore, in view of his poor health and active life, that Bergman died at the

[4] THOMSON, "History of chemistry," Colburn and Bentley, London, 1830, Vol. II, p. 33.

age of forty-nine years on July 8, 1784, at a bath in Sweden near Wittern.

The twenty-eight years allowed him after the publication of his first paper in 1756 were richly productive; though his research activity was confined mainly to the field of chemistry, within that field his interests were broad. His publications include a book on the doctrine of affinity published in 1773, an enlarged edition of which followed in 1783; a book on blowpipe analysis published in Vienna in 1779; "Sciographia regni mineralis," a new classification of minerals based on chemical constitution, 1782; three volumes of collected works called "Opuscula physica et chemica" appearing 1779–83; and the last three volumes of his works published in Leipzig in 1787–90 after his death. The first four volumes are devoted entirely to chemistry, the others also to natural history, electricity, and astronomy. These volumes contain all of his works except the "Sciographia." All of these books except that on the blowpipe were translated from the original Latin into French and German, the "Sciographia" also into English.

The blowpipe was first used by Florentine glass blowers in 1660, then by goldsmiths for soldering. In 1679 Kunkel first described the use of bellows and charcoal blocks. In 1739 Cramer, like Kunkel a metallurgist and mineralogist, used a copper blowpipe. It was introduced into purely chemical processes by the Swedish chemist Cronstedt who, incidentally, used minerals in amounts as small as a pinhead and directed the flame of a candle against these small portions. Though Wallerius in 1750 mentions it as part of the essential equipment of an analyst, Bergman gives the first complete description of it, distinguishing between the inner and outer flame, giving directions for its use with soda, borax, phosphate, etc., and reporting the behavior of earths, salts, combustible materials, calxes, metals, and ores with the blowpipe. He used the blowpipe with charcoal blocks, with gold and silver spoons. Gahn, his pupil, was much more successful in the use of this important tool than Bergman himself and suggested many improvements.

Up to the time of Bergman, minerals were classified according to their hardness, color, crystal form. Bergman tried to classify them according to their constitution. In order to do this he had to develop the first complete method of analysis of minerals in the wet way. He identified metallic constituents by their precipitation reactions rather than by reducing them to their metallic form, and is first again in pointing out that most minerals will dissolve in hydrochloric acid after they are finely powdered, and that those insoluble in acid even at high temperatures can be "opened up" with potassium carbonate. He was the first to emphasize the importance of the choice and the function of a reagent. Many of our routine reagents he also used: barium chloride for sulfuric acid and sulfates; lime water for carbon dioxide; litmus paper to detect the presence of free acids; potassium ferrocyanide to detect iron and copper; silver nitrate for hydrochloric acid, chlorides, and hydrogen sulfide; oxalic acid for lime; and ammonium and alkali carbonates for the precipitation of metals and earths. Bergman's "Treatise on Mineral Waters," published in 1778, contained the first general method of water analysis ever published, a method used for over twenty years until Kirwan improved on it by developing a shorter, easier, and more accurate system.

Bergman's greatest contribution to quantitative analysis was the idea that a constituent did not necessarily have to be determined in its elemental condition but that it could be isolated in the form of a well-known compound. For many of his fusions he used iron crucibles rather than the more readily corroded earthenware. He analyzed qualitatively and quantitatively an amazing number of ores, stones, mineral waters, and minerals. But little can be said for the accuracy of his analyses. Other chemists using Bergman's method and the same reagents obtained better results, but the chemical world, respecting the name of Bergman, attempted always to check his results and ignored those of superior analysts, such as Wenzel, whose name was almost unknown.

Although Bergman's name is not mentioned in the "Handbook of Chemistry and Physics" in connection with the discovery of a single element, yet he had a share in the early study of several. He suspected a new metal in pyrolusite, could not find it, and asked Gahn to continue the problem, resulting in the discovery of manganese in 1774. With Scheele he believed that the minerals tungsten and wolfram contained a new element and gave that problem to the Elhuyar brothers in 1784. Bergman just missed finding zirconium in zircon and molybdenum in native molybdenum sulfide. His student Hjelm isolated molybdenum six years after Bergman's death.

A brief mention of some of the subjects of his papers other than those already mentioned might be of interest: on the difference between cast iron, wrought iron, steel; on products of volcanoes; on the aerial acid (in which he gives Cavendish no credit for work he had already published); on oxalic acid (in which he again omits the name of Scheele, whose work on this acid had already been done and was undoubtedly known to Bergman); on magnesia (in which he does mention Black); and on silica, which he did not know to have acid properties. Bergman's close adherence to the phlogiston theory is decidedly disappointing. Though he was among the first to apply quantitative methods to the study of combustion processes, the fact that a metal gained in weight while losing phlogiston troubled him not a moment. He even determined the relative phlogiston content of all the metals by their reactions with acids. Thus Bergman performed the first experiments that could have emphasized the idea of equivalents, which neither he nor Lavoisier did. His figures were used by Lavoisier with his own explanations, but until his death Bergman believed in the phlogiston theory.

Throughout his career Bergman was interested in reforming the nomenclature of chemistry. It was

through his influence that Guyton de Morveau returned to Paris in 1782 with the express purpose of establishing a uniform system of nomenclature based on the phlogiston theory. The French schools, headed by Lavoisier, were naturally opposed to such a system. Through their influence Bergman lost the support of Morveau, who was converted to antiphlogistic views. Since, in addition to this, Bergman was quite inconsistent in the use of the system he proposed, it was not generally adopted. Bergman also tried to introduce a general system of symbols. He suggested that metals be represented by varying crowns, salts and alkalies by circles, and acids by crosses. Of importance in this connection is the fact that Bergman was the first person to use a combination of symbols to indicate at a glance the nature of the compound. However, his inconsistency here, too, was at least partly responsible for the fact that although the system received much attention it was never generally used.

Bergman's reputation in chemistry rests as much upon his work on affinity as upon his development of methods of analytical chemistry. Up to 1775 there had arisen two distinct schools of thought on affinity. According to one group, headed by Geoffroy, "any substance a has a definite intensity of affinity by which it is united to another body x. When a third body b, having a greater affinity for x than a has, is presented to the compound, a is displaced and b unites in its stead with the body x."[5] The other group held, of course, that no difference in intensity of affinity exists, that is, that b might displace a, but that a in turn could displace b under proper conditions. Geoffroy's views were given great weight and popularized by the fact that Bergman adopted and taught them in his "De attractionibus electivis" which first appeared in the *Memoirs* of the Royal Society of Upsala in 1775 and was later translated into English by Dr. Beddoes, Davy's friend. In this thesis Bergman stated that all bodies capable of combining chemically with each other have an attraction for each other which is a definite and fixed force capable of being represented by a number. He then proceeded to draw up his famous fifty-nine tables of affinity, each headed by one substance under which were placed all the bodies that reacted with it in order of affinity. Bergman's tables differed from others of their kind in that they were based on more accurate analyses, were more complete, and also for the first time, following a suggestion made by Baumé, made a distinction between affinities for reactions in solutions at room temperature and in the dry way at elevated temperatures. Every chemist of the time was convinced of the correctness of Bergman's views in this respect, and nearly everyone used his tables. A new element or compound had to find its place in these tables before it could be considered a legitimate substance. Until Berthollet's dissertation on affinity was published in 1803, Bergman's views were unchallenged. Berthollet, who believed that affinity was not elective but was dependent on the mass and shape of bodies, and that increased mass meant increased affinity, was logically led to the conclusion that substances must be able to unite with each other in all proportions, while Bergman held that substances could unite in certain proportions only.

As Davy is credited with the discovery of Faraday, so Bergman is often thought of as the discoverer of Scheele. Although Scheele was greatly indebted to Bergman in many ways, Bergman can hardly be given the honor of having found Scheele. Actually it is Gahn to whom credit is due here, too, as in so many other cases, although to Bergman was given the first opportunity of recognizing the talents of Scheele. When the latter had written his first paper, the result of his first research on tartaric acid and its compounds, he sent it to Bergman, expecting that it would be read before the Stockholm Academy of Sciences and published in its *Memoirs*. Bergman, a very busy man, set this paper by an unknown author aside without reading it, intending to study it later. However, he forgot all about it. Scheele then sent a copy of the paper to Retzius, who shortly thereafter incorporated the information contained therein into a paper of his own without ever mentioning the name of Scheele. Naturally, this experience made Scheele very bitter. It appears that Scheele may have tried on another occasion to send a paper to Bergman, that it was read but not published, probably on account of a certain awkwardness of style. Bergman's attention was drawn to Scheele in quite another manner. Bergman had purchased from the apothecary Lokk some potassium nitrate, which to his amazement behaved quite differently after ignition than before. He was unable to explain the formation of brown fumes on addition of acetic acid to the ignited salt. Neither could Lokk nor Gahn account for these facts. It was Gahn who then discovered that the young apprentice in Lokk's shop, Scheele, understood the reaction perfectly. When Gahn informed Bergman of this fact, the latter was intensely eager to meet Scheele, who, however, did not share this enthusiasm, due to his earlier disappointing treatment at Bergman's hands. It required repeated efforts on the part of Bergman and persistent persuasion by Gahn to make Scheele willing to meet the great Bergman. Finally Scheele did consent to a meeting, which led to a friendship between these two men that lasted until Bergman's death. Scheele benefited socially from Bergman's support and Bergman suggested many of the investigations that Scheele carried out, such as the study of pyrolusite which led to important theoretical and practical results. Retzius writes of their friendship: "It is difficult to say whether Scheele or Bergman was *docens* or *discens*, for unquestionably Bergman obtained the greatest part of his practical knowledge from Scheele, while on the other hand Scheele is indebted to Bergman for the fact that in later years his understanding was clearer than earlier."[6]

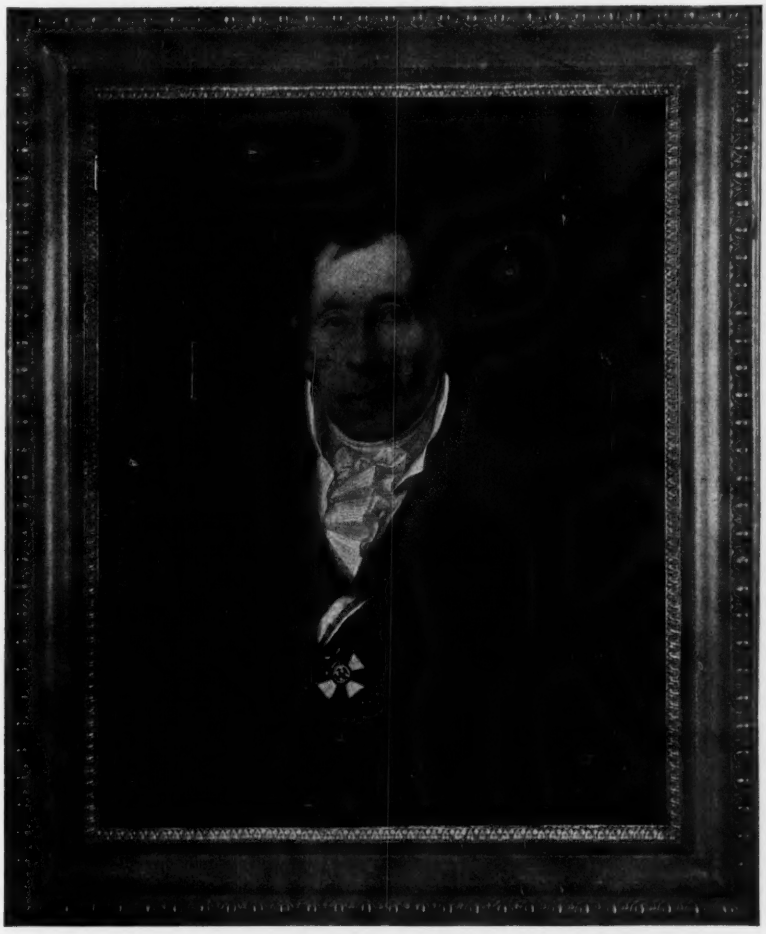
[5] THOMSON "History of Chemistry," *op. cit.*, Vol. XI, p. 9.

[6] BUGGE, "Das Buch der Grossen Chemiker," Verlag Chemie, Berlin, 1929, Vol. I, p. 276.

Translations from the French and German are the author's.

Bergman's most striking scientific characteristic is his perpetual emphasis on continued investigation. He deplored any inclination to be carried away with an enthusiasm for explaining more than had been definitely experienced. One could wish, however, that several other facts might be reported differently: that he had given more credit where credit was due, particularly to Gahn and Scheele; that he could himself have been a better experimenter and thus actually, instead of only nearly, have discovered a few elements; that he had been a leader in antiphlogistic thinking; and that he could have carried through some of his reforms. However, Bergman was a pioneer in analytical chemistry and as such he built for it a firm foundation which has not as yet been changed in essential respects.

While Bergman is considered the founder of analytical chemistry, and deservedly so, Klaproth, the greatest German chemist of his time and one of the greatest in all Europe, is often referred to as the creator of the art of analytical chemistry. Unlike Bergman, Klaproth is noted for the superb quality of his work rather than its quantity; for finishing, improving, refining existing methods rather than opening fields for others to continue; for being himself a master analyst, excelled by none of his contemporaries and equalled by few; for making it possible to have analyses duplicated with much greater accuracy than before his time.



Courtesy of the Fisher Scientific Company

MARTIN HEINRICH KLAPROTH, 1743–1817

Martin Heinrich Klaproth was born in Wernigerode, in the Harz, on December 1, 1743, when Lavoisier was three months old. Eight years later a fire destroyed all of his father's property and goods, leaving the family impoverished. Martin and his two brothers helped to earn their education in the village school. The older brother later became a clergyman, the younger a private secretary and Keeper of the Archives of the government in Berlin. Martin sang in the village choir to earn money for a schooling which he hoped would prepare him for service in the church (he remained all his

life a deeply religious man) but the "unmerited hard treatment he met at school so disinclined him to study"[7] that, at sixteen, he decided to learn the apothecary's trade. Why Klaproth was harshly treated is not stated. For five years he was an apprentice and for two more years an assistant in the laboratory at Quedlinberg. From 1766–8 he assisted in the public laboratory at Hanover. Here he had access for the first time to some books on chemistry which so stimulated his intellectual interest that he became eager to go to Berlin to study under Henkel, Rose, Pott or Marggraf. In 1768 he went to Wendland's laboratory in Berlin (at the sign of the Golden Eagle in the Street of the Moors) where he continued studying chemistry and where he also studied Latin and Greek with the help of a clergyman. At the end of 1770 he went to Danzig where he worked in a laboratory for several months, returning to Berlin in March, 1771, to the laboratory of Valentine Rose. In June of the same year Rose died, requesting on his deathbed that Klaproth be made his successor. Klaproth characteristically not only felt it his duty to take over the direction of the laboratory, but also to care for the two young sons of Rose. The younger of the two died; the other, Valentine Rose the younger, became Klaproth's assistant, with whom he published many papers. This Valentine Rose was the father of Heinrich Rose, the third great chemist in that family.

In 1782 Klaproth passed a brilliant examination for an apothecary's license and presented a paper on "Phosphorus and Distilled Waters." In the same year he bought the Flemming Laboratories and shortly thereafter married Sophie Christiana Lekman. They had three daughters and one son, the famous orientalist Heinrich Julius Klaproth, who became adjunct in Oriental Languages to the Academy in St. Petersburg. In 1800 Klaproth bought the room of the Academical Chemists where he experimented, lectured, and kept his mineralogical and chemical collection. His laboratory soon became a model "conducted upon the most excellent principles and governed with the most conscientious integrity."[8]

During these years Klaproth was a frequent contributor to the *Memoirs* of the Berlin Academy, Crell's *Annalen*, Köhler's *Journal*, and Gehlen's *Journal*. Each paper represented a definite contribution either correcting a false impression, extending views of the time, presenting new analyses, or reporting on new elements. By 1800 Klaproth was Professor at the Royal War School, Professor at the Royal Mining Institute, member of the College of Sanitation, the Berlin Academy of Arts, the Berlin Academy of Sciences. All of Europe knew him as a great chemist. It was not surprising, therefore, that in 1811 the King of Prussia conferred on him the Order of the Red Eagle or that in 1810, when the University of Berlin was founded, Klaproth was appointed as its first Ordinary Professor of Chemistry, although he was then sixty-seven years old. This post Klaproth filled successfully until his death on January 1, 1817. The post was then offered successively to Berzelius, who declined it because he was satisfied with conditions at home, to Leopold Gmelin, who remained instead in Heidelberg, and to Mitscherlich, who accepted it.

Klaproth devoted his entire life to scientific pursuits. The brief discussion here presented concerns his most important contributions. Just as his actual analyses were characterized by extreme accuracy so, for the first time, was his method of reporting results an accurate one. Where in the analysis of minerals the per cent of the constituents did not exactly sum up to one hundred, it was the habit of analysts, Bergman included, to make corrections either by recalculating the per cent determined in order to have a summation of exactly one hundred per cent or by changing the per cent found according to a preconceived notion of what had been gained or lost. Klaproth was the first person to report in his publications the actual "uncorrected" data obtained, giving the weight of the mineral employed and the weights of the constituents obtained. Thus errors in the analyses were no longer hidden, and attention was focused on the source and elimination of errors, amounting usually to about 0.5 to 2 per cent. This practice, introduced by Klaproth, called attention to small amounts and has led to the discovery of many substances, from Klaproth's own discovery of potash in minerals to the discovery of the inert gases. As his method of recording results is our model even today, so his actual methods of analyses served as a model for many years. Those minerals which failed to yield to the carbonate treatment of Bergman, Klaproth ground to a very fine powder, digested in potash, and fused in a silver crucible. Where potash was contained in the mineral, Kalproth substituted the use of barium carbonate. He placed a great deal of emphasis on knowing the purity of the reagents used, of purifying them if necessary, and on the careful choice of apparatus. He was also the first person to bring precipitates to constant weight by drying or igniting them. For grinding he used either flint or agate mortars, in extreme cases diamond mortars. He substituted silver crucibles for iron wherever the temperature required would allow it. He determined the actual amount and nature of the loss suffered by the mortar or the crucible and made appropriate corrections.

In the course of his analyses Klaproth contributed to the early history of a fair number of elements, discovering two, verifying the discovery of two others, and assisting in the study of several others. In 1789 he found that pitchblende, which was thought to contain only zinc or iron, must contain another element which, in honor of Herschel's recently discovered planet, he called "uranium." The element was isolated by Peligot fifty years later when platinum crucibles were available. Because of its similarity to alumina, zirconia was overlooked in mineral analysis until 1789 when Klaproth discovered it in zircon. In 1795 he found it in hyacinth, called "jacinth" in Revelations where it is mentioned

[7] THOMSON, "History of chemistry," *op. cit.*, Vol. II, p. 192.
[8] *Ibid.*, Vol. II, p. 230.

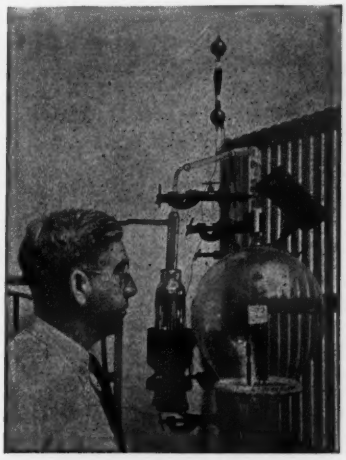
as one of the precious stones decorating the walls of Jerusalem. Berzelius isolated zirconium. In 1793 Klaproth first distinguished between barium carbonate and strontium carbonate. In 1795 he separated from iron oxide the oxide of an element which he named titanium. Rose later improved the method. Klaproth, a great reader of the literature, realized that the oxide described by Gregor of Cornwall in 1791 was the same as his oxide and gave full credit for its discovery to Gregor of Cornwall. This element was not isolated until 1910. In 1798 Klaproth delivered a paper before the Berlin Academy of Sciences on Transylvanian gold ore. In this ore he had found a new white metal. Müller von Reichenstein had suspected a new element in this ore in 1782, and sent a specimen of it to Bergman who, however, reported only that the element was not antimony. Klaproth, crediting Müller with the discovery, named this element tellurium. In 1804 Klaproth discovered an oxide in yttria which he called cereria. He confirmed the discovery of chromium and glucinum by Vauquelin and of ytterbium by Gadolin. As Hofmann said, "If one considers how rarely it is the fortune of a chemist to find a single element, it can be understood how greatly Klaproth's discovery of four elements must have impressed his contemporaries."[9]

In 1795 was published the six volume collection of his works, "Beitrage zur Chemischen Kentnisse der Mineralkörper." Klaproth assisted also in the translation by Fischer of Berthollet on affinity and chemical statics, in the publication of a chemical dictionary, and in editing Gren's "Manual of Chemistry," to which he made remarkable corrections rather than additions.

Phlogistic ideas had taken an especially strong hold on German chemists because of strong nationalistic feeling, particularly against the French. Though he had been a student of Marggraf, disciple of Stahl, Klaproth, free from all prejudice, suggested to the Berlin Academy in 1792 that experiments on combustion and calcination be subjected to exact revision. The results confirmed Lavoisier's conclusions and the Berlin Academy was itself converted, which brought about the conversion of other German groups to antiphlogistic doctrines.

Klaproth, like Vauquelin, tacitly assumed the Law of Definite Proportions and helped to settle the controversy of 1801–7, in which Berthollet and Proust led opposite camps.

To quote again from Thomas Thomson: "Amidst all these labours it is difficult to say whether we should most admire the fortunate genius which, in all cases, easily divined the point where anything of importance lay concealed; or the acuteness which enabled him to find the best means of accomplishing his object; or the unceasing labour and incomparable exactness with which he developed it; or the pure scientific feeling under which he acted, and which was removed at the utmost possible distance from every selfish, every avaricious, and every contentious purpose."[10] He had the valuable gift, according to Kopp,[11] of knowing how to keep scientific discussions impersonal. The only recorded instance of any unpleasantness between Klaproth and his fellow scientists is found in Berzelius' autobiography.[12] Berzelius and Hisinger had found in heavy spar a new substance having two stages of oxidation, one colored and one not, had called this substance "cerium" and sent a report on it to Gehlen's *Journal.* Gehlen responded that Klaproth had preceded them in discovering a new substance in the same mineral, that Klaproth's paper would be published in the current issue of his journal, and Berzelius' in the following. Honors for the discovery were to be shared between Klaproth and Berzelius. When this news reached Paris, an enthusiastic group of the Swedish chemists working there were eager that Berzelius' priority should be established. Their feverish activity lead Vauquelin to write in the *Annales de Chimie* that "Klaproth's reputation makes very unlikely the idea that Klaproth wished to attribute to himself the work of another." Klaproth, reading this, was incensed. Berzelius writes: "Klaproth, who must have been a somewhat gruff man, anathemized me in a very forcible letter, saying that he and Valentine Rose had known this substance since 1784 and that he wanted to know through which correspondent in Paris such a shameless untruth had arisen." Berzelius answered that he was a new chemist, had no correspondents in Paris, and was ignorant of the statement made until so informed by Klaproth himself. To this explanation Berzelius received no answer. He writes: "That was the only thing I ever had to do with



Courtesy of the Fisher Scientific Company

SINTERING URANIUM, WHICH WAS DISCOVERED BY KLAPROTH, IN HIGH-FREQUENCY VACUUM APPARATUS AT THE WESTINGHOUSE LAMP COMPANY

[9] BUGGE, *op. cit.*, p. 338.
[10] THOMSON, "History of chemistry," *op. cit.*, Vol. II, p. 232.
[11] KOPP, "Geschichte der Chemie," Friedrich Vieweg und Sohn, Braunschweig, **1843,** Vol. I, p. 344.
[12] BERZELIUS, "Autobiographische Aufzeichnungen," in KAHLBAUM, "Monographien aus der Geschichte der Chemie," Leipzig, **1903,** Vol. VII, p. 36.

this great chemist." Klaproth objected to the name "cerium," and suggested "cererium" instead. For some time either name was used depending upon the direction of allegiance of the particular chemist. Thus in 1825 Wöhler, writing from Berlin to his former professor, Berzelius, mentions the fact that Leonhard, for whom Wöhler was translating Hisinger's "Mineralogy," used the form "cererium" but that he would much prefer to use "cerium."[13] A final impression of Klaproth we have in the memorable words of A. W. von Hofmann: "with a modesty far removed from vainglory, ready to recognize fully the merits of others, considerate of their weaknesses but of unrelenting severity in the criticism of his own work, Klaproth has furnished us for all time with a model of the true scientist."[14]

[13] WALLACH, "Briefwächsel zwischen Berzelius and Wöhler," Engelman, Leipzig, **1901**, Vol. I, p. 31.
[14] BUGGE, *op. cit.*, p. 341.

(To be continued)

OTTO HÖNIGSCHMID

(Frontispiece)

DESPITE the imperative necessity of agreement on atomic weights, it was not until December, 1893, that an official table was issued. This was prepared by F. W. Clarke at the request of the American Chemical Society, which also sponsored his succeeding annual reports. In 1898, the German Chemical Society published its first table of approved values. Pursuant to a suggestion by its committee, an invitation was sent from Berlin in March, 1899, to the chemical societies and other interested organizations asking their coöperation in preparing and issuing a table of correct atomic weights. More than fifty representatives were appointed; they organized by mail and in due course named a working committee: Clarke, Seubert, Thorpe. In 1904 Moissan was added; Seubert was succeeded by Ostwald in 1906, and at Moissan's death (1907) Urbain took his place. This International Committee on Atomic Weights issued annual tables from 1903 on. In 1913 it was placed under the aegis of the Council of the International Association of Chemical Societies. The last report signed by the full committee was that of September, 1915. The war then interfered with free correspondence, personal hostilities intervened, but the so-called International Tables were put out regularly (except in 1918), though in fact they were little more than re-promulgations of the pre-war values, because the committee members were chiefly employed in war activities and atomic weight work had largely been interrupted. Ostwald, isolated, proclaimed the 1916 table for 1917, 1918, 1919. At the close of the war, coöperation was not resumed, the committee functioned without German representation.

A newly organized German Atomic Weight Commission issued its first table in 1921. The International Union of Pure and Applied Chemistry, successor to the Association of Chemical Societies which was dissolved during the war, in 1921 created an International Committee on Chemical Elements, one of whose three divisions was to prepare the table of atomic weights. The only report was issued in 1925. In 1921, the Swiss Chemical Society had a table prepared that, except for unusual changes, was to be valid until 1930. Three tables, 1922–4, were issued by a Spanish committee. In 1927, Baxter, who for many years had prepared an annual report on atomic weight measurements for the American Chemical Society, put out a table over his own signature. The Chemical Society (London) issued a table in 1929. Consequently, in 1929 there were current no less than six atomic weight tables: three discordant and rather out of date, and three recent which agreed closely with each other. This ridiculous situation was relieved in 1930, when the International Union of Chemistry united all countries and created its Committee on Atomic Weights to present yearly a table based on the best evidence.

Otto Hönigschmid, after Ostwald's retirement in 1922, became chairman and leading spirit of the German Atomic Weight Commission; he has been a member of the International Committee since its creation in 1930. Hönigschmid was born at Horowitz, Bohemia, on March 13, 1878. He studied chemistry at the German University of Prague (Ph.D. 1901) and supplemented this training in Moissan's laboratory at the Sorbonne (1904–06), at Harvard (1909–10) under Richards, and at the Radium Institute in Vienna (1910–11), where he made the first accurate determination of the atomic weight of radium.

In 1908 he was privatdozent at his alma mater, in 1911 he was appointed ordinarius and director of the laboratory for inorganic and analytical chemistry at the Technical High School in Prague. His real life work was begun in 1918 when he went to the University of Munich, where he founded and has since directed the German Atomic Weight Laboratory.

Professor Hönigschmid and his collaborators have determined the atomic weights of no fewer than forty elements, including the first figures for rhenium and hafnium. Their results are reflected in numerous revisions of the values adopted in the official tables. These accomplishments have involved remarkable refinements in preparative and analytical procedures. The accuracy of the results and the exceptional attention even to minute details betray the expert knowledge, the persistence, and the devotion of this master analyst.

One of Hönigschmid's specialties has been the application of atomic weight determinations to radioactivity and isotopy. His exact work on radium, uranium, uranium lead, thorium, ionium, and thorium lead furnished striking confirmation of the hypothesis of atomic disintegration advanced by Rutherford and Soddy. In 1934, when he re-examined the atomic weight of radium, the Belgian Radium Corporation lent him the enormous weight, five grams, of radium bromide, whose market value was about $240,000.

Although it is now known that most elements present themselves as mixtures of two or more isotopes, these are usually so resistant to segregation, and almost always occur in such unvarying proportions, that the mean (chemical) atomic weights are still the most fundamental values for stoichiometry. The results given by the mass spectroscope and by the balance are mutually stimulating. Hönigschmid was the first to establish by atomic weight determinations the shift in the isotopic ratio of ordinary elements (potassium, mercury) that had been subjected to "ideal distillation" by von Hevesy.

Many deserved honors have come to Otto Hönigschmid, but invitations to head chemical departments elsewhere have been declined because he feels that he can serve science and education best by remaining as chief of what the Müncheners call the "Atomlabor." On the occasion of his sixtieth birthday, a Festschrift of the *Zeitschrift für anorganische und allgemeine Chemie* was published.

—Contributed by Ralph E. Oesper, University of Cincinnati

Chemical Prefaces

HUGH J. McDONALD
Illinois Institute of Technology, Chicago, Illinois

CHRISTOPHER MORLEY, in his essay on "Prefaces,"[1] has said:

"It has long been my conviction that the most graceful function of authorship is the writing of prefaces. What is more pleasant than dashing off those few pages of genial introduction after all the dreary months of spading at the text? A paragraph or two as to the intentions of the book; allusions to the unexpected difficulties encountered during composition; neatly phrased gratitude to eminent friends who have given gracious assistance; and a touching allusion to the Critic on the Hearth who has done the indexing. A pious wish to receive criticisms 'in case a second edition should be called for'; your address, and the date, add a homely touch at the end.

"How delightful this bit of pleasant intimacy after the real toil is over! It is like paterfamilias coming out of his house at dusk, after the hard day's work, to read his newspaper on the doorstep. Or it may be a bit of superb gesturing. No book is complete without a preface. Better a preface without a book ....."

Many will agree with this sentiment. In a scientific work a preface should be a graceful introduction, as the pathway to the home, as the extended hand of greeting of the author to his reader, and not a lengthy compilation of acknowledgments and sources. Such matter belongs rightfully in footnotes or perhaps at the end of the book. Not that a few acknowledgments have no place in a preface, but rather that the absence of many acknowledgments helps it. Just as a host does not turn from the guest of honor to thank his wife for preparing the dinner, so should an author not leave his reader poised on the threshold of his book while acknowledging the help of the many friends who contributed to its building.

In the preface the author has an opportunity to reflect some of his personality and character. From its perusal the reader will form his opinion of the author as an individual, and of his philosophy and temperament. Whether he is to be remembered as warm and sunlit, or cold and austere, will depend in large measure on the unconscious decision that is then reached. Has there ever been an author who did not wish to obtain the personal esteem of his readers? Yet all too few have taken due advantage of the preface as a means to that end.

In the literature of chemistry, a preface that is interesting, and still fresh, although written almost sixty years ago, is that of Dmitri Mendeleeff in his "The Principles of Chemistry." Many of us retain in our memories images of great men, images gained from poor photographs or paintings made late in their lives. In my student days Mendeleeff was envisaged as a very old man seated at a table in an ill-lighted room, hard at work on a manuscript. It is difficult from such associations to endow the man with life and accomplishment, but on reading his preface the scientist comes to life—we can hear his voice, see the penetrating glance of his bright blue eyes, and feel the freshness of thought that marked so many of his improvisations of argument for and against each topic he discussed. Two excerpts from this remarkable preface are:

"Experimental and practical data occupy their place, but the philosophical principles of our science form the chief theme of the work. In former times sciences, like bridges, could only be built by supporting them on a few broad buttresses and long girders. In addition to the exposition of the principles of chemistry, it has been my desire to show how science has now been built up like a suspension bridge, supported by the united strength of a number of slender, but firmly fixed, chains, which individually are of little strength, and has thus been carried over difficulties which before appeared insuperable. In comparing the science of the past, the present, and the future, in placing the particulars of its restricted experiments side by side with its aspirations after unbounded and infinite truth, and in restraining myself from yielding to a bias towards the most attractive path, I have endeavoured to incite in the reader a spirit of inquiry, which, dissatisfied with speculative reasonings alone, should subject every idea to experiment, encourage the habit of stubborn work, and excite a search for fresh chains of evidence to complete the bridge over the bottomless unknown. History proves that it is possible by this means to avoid two equally pernicious extremes, the Utopian—a visionary contemplation which proceeds from a current of thought only—and the stagnant realism which is content with bare facts. Sciences like chemistry, which deal with ideas as well as with material substances, and create a possibility of immediately verifying that which has been or may be discovered or assumed, demonstrate at every step that the work of the past has availed much, and that without it, it would be impossible to advance into the ocean of the unknown."

Again:

"The time has arrived when a knowledge of physics and chemistry forms as important a part of education as that of the classics did two centuries ago. In those days the nations which excelled in classical learnings stood foremost, just as now the most advanced are those which are superior in the knowledge of the natural sciences, for they form the strength and characteristic of our times."

Another example of a preface to a work of chemistry, which has called forth expressions of admiration from many readers, is that of Lewis and Randall, to their great work, "Thermodynamics and the Free Energy of Chemical Substances,"[2] a volume which has probably influenced the science of chemistry more than any other contribution to chemical literature in America since the time of Willard Gibbs. Some excerpts from this scholarly introduction are:

[1] MORLEY, "Shandygaff," Garden City Publishing Co., Inc., Garden City, N. Y., 1918.

[2] LEWIS AND RANDALL, "Thermodynamics and the free energy of chemical substances," McGraw-Hill Book Co., Inc., New York City, 1923.

"There are ancient cathedrals which, apart from their consecrated purpose, inspire solemnity and awe. Even the curious visitor speaks of serious things, with hushed voice, and as each whisper reverberates through the vaulted nave, the returning echo seems to bear a message of mystery. The labor of generations of architects and artisans has been forgotten, the scaffolding erected for their toil has long since been removed, their mistakes have been erased, or have become hidden by the dust of centuries. Seeing only the perfection of the completed whole, we are impressed as by some superhuman agency. But sometimes we enter such an edifice that is still partly under construction; then the sound of hammers, the reek of tobacco, the trivial jests bandied from workman to workman, enable us to realize that these great structures are but the result of giving to ordinary human effort a direction and a purpose.

"Science has its cathedrals, built by the efforts of a few architects and of many workers. In these loftier monuments of scientific thought a tradition has arisen whereby the friendly usages of colloquial speech give way to a certain severity and formality. While this may sometimes promote precise thinking, it more often results in the intimidation of the neophyte. Therefore we have attempted, while conducting the reader through the classic edifice of thermodynamics, into the workshops where construction is now in progress, to temper the customary severity of the science in so far as is compatible with clarity of thought."

In his book on "The Properties of Silica,"[3] Sosman states what he believes to be the recognized role of the preface, then proceeds to enlarge that role. From his word picture of the super-scientist and of the ideal book, another picture, that of the author, forms in the mind of the reader. It is a pleasant mental sketch that one draws, even from reading a short excerpt from the preface such as the following:

"The recognized function of a preface is to give the history of the work, but I shall venture to enlarge that function by indicating what is my ideal for such a book.

"Often, while trying to extract a meaning from a lot of apparently unrelated facts resulting from my own experiments or obtained by other workers on silica and the silicates, have I wished that I could turn freely to some individual who combined in one brain all of Bohr's and Rutherford's insight into the structure of the atoms, Gibbs' and Planck's comprehension of the relations between energy and the forms of matter, Maxwell's and Drude's penetration into the principles of electric and radiant energy, together with the detailed knowledge of silica possessed by Dana, Des Cloizeaux, Rose, and a host of others. I have dreamed of inducing this super-scientist to write for me a book which should show how all the many qualities which we define and measure and call 'properties' are interrelated, and how each is related to the constitution and structure of silica and the silicates, all this to be in language such that any of us of average intelligence and experience—whether student, researcher, ceramic engineer, or petrologist—would be able to understand the facts and principles and apply them to his daily problems.

"One of the outstanding characteristics of this ideal book would be its brevity. The properties of matter as exemplified in silica would appear as a homogeneous whole, not parceled out into chapters, each the exclusive province of a certain group of specialists.

"An even more important characteristic of the ideal treatise would be that the second edition, incorporating all the results of the latest research, would be shorter than the first edition. This shrinkage in size would follow logically from the principle that science is organized knowledge—the more knowledge, the better the organization."

[3] SOSMAN, "The properties of silica," The Chemical Catalog Co., Inc., New York City, 1927.

The preface allows an author to speak directly to his readers. It gives him a chance to air his personal views on matters touched on in the main text and, perhaps, to defend his stand. An example of this perfectly legitimate use of the preface is found in B. T. Brooks' "The Non-benzenoid Hydrocarbons."[4]

"The reader seeking only material of industrial interest may object to the inclusion of much subject matter which is solely of theoretical interest, and the searcher who scorns industrial processes will find much in the present volume that is unorthodox. The author desires to make no apology for the inclusion of both classes of subject matter; the description of any special subject of science should be systematic if we are to retain our conception of science as classified knowledge, and the author does not feel that descriptions of industrial processes and references to patent literature detract from the value of the compilation, considered as a scientific monograph. In a treatise of purely industrial purpose, the checker-board plan, in which economic value determines the exclusion or inclusion of subject matter, may perhaps be justified, but the author believes that the best results will be obtained by broader scientific treatment of industrial subjects. The author is well aware that patent literature, in spite of oaths and notaries' seals, is not bound by the same standards of truth that govern the publication of purely scientific papers and has accordingly treated such matter critically and with caution."

Joel H. Hildebrand in his monograph, "Solubility of Non-electrolytes,"[5] uses part of the preface to tell his readers of his own modest hopes for the book and of his fears as to how it will be received. For those who read the preface, the book is bound to be received well. An excerpt to justify this view is:

"The writing of a preface, always in fact a postscript, finds the author in a state of humility and disillusion likely to be exceeded only after the appearance of some reviews. The subject is complicated and I am conscious of the incomplete character of much of the theory and evidence here presented. This may, however, be not altogether unfortunate, for what the book lacks in finality it may gain in stimulus to research. While it may redound more to the credit of an explorer to exhibit a finished map, it is more exciting to his audience to see a region labeled 'unexplored.' I have tried, accordingly, to point out the many discrepancies and disturbing factors."

In their book on "The Free Energies of Some Organic Compounds,"[6] Parks and Huffman, in carefully phrased, diplomatic fashion, suggest, in the preface, the application of thermodynamics to organic problems as an addition to the tools of the organic chemist.

"The organic chemist has been remarkably successful in developing his science, primarily with the aid of one tool—the principle of valence. By means of this tool he has been able to classify more than one-quarter of a million compounds and to correlate their properties in a highly satisfactory manner. Again by means of it he has predicted the possible existence of numerous compounds, hitherto unknown, and, through his previous correlations, has devised methods of preparing such compounds. And, in view of the present-day achievements of organic chemistry, rash indeed would be the man who might attempt to minimize the value of such a tool.

[4] BROOKS, "The non-benzenoid hydrocarbons," The Chemical Catalog Co., Inc., New York City, 1922.

[5] HILDEBRAND, "Solubility of non-electrolytes," 2nd ed., Reinhold Publishing Corporation, New York City, 1936.

[6] PARKS AND HUFFMAN, "The free energies of some organic compounds," The Chemical Catalog Co., Inc., A. C. S. Monograph Series, No. 60, New York City, 1932.

"We believe, however, that the time is now fast approaching when the orthodox organic chemist will find it advantageous to add to his kit some of those tools—thermodynamics, statistical mechanics and quantum theory—which have proven so helpful to his brother, the physical chemist. These newer tools will be added, not in order to discard those which the organic chemist has already employed so successfully, but rather to supplement and reinforce the latter, particularly in the solution of special problems. It is to facilitate the application of one of these tools, thermodynamics, to organic chemistry that we have undertaken the present task."

A successful practice in the writing of prefaces is to include a brief paragraph or two dealing with the origin of the subject, with references to mythology or examples from ancient beliefs as to the status of the subject in the days when man was young, then to pass quickly to the modern panorama. Such contrasts or comparisons drive home the idea of progress in a very satisfying way. A citation from the book of Marek and Hahn[7] on catalytic oxidation of organic compounds in the vapor phase will illustrate this contention:

"When—because of the prodigality of his brother, Epimetheus, in bestowing upon the animals of his creation all of the splendid gifts of the gods—Prometheus had no worthy blessing to give his master work, man, he ascended to heaven, lighted his torch at the chariot of the sun, and brought down fire. With fire man could then conquer the earth and mold it to his use.

"Other than in mythology and in the imagination of erstwhile historians, we have no intimation of the origin of fire on the earth. However, man's own record shows that for many thousands of years he knew and used fire, and the progress of civilization may be measured in terms expressing the extent to which fire has been used. The oldest writings of India taught that fire was one of the elements, and the history of alchemy teems with speculations on its cause and use. Long ages passed before the empirical knowledge of primitive man and the speculations of the alchemists were woven with scientific observations into a credible theory and explanation of fire, combustion, and oxidation."

The preface has had a noble past; it can have a bright future only if rescued from the abuses to which it is now commonly subjected, namely, a tendency to make it almost wholly a list of acknowledgments of one kind and another.

[7] MAREK AND HAHN, "The catalytic oxidation of organic compounds in the vapor phase," The Chemical Catalog Co., Inc., A. C. S. Monograph Series, New York City, 1932.

An Improved Method for the Preparation of Chloroform

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IT IS a fact to be regretted that many of the more recent laboratory manuals in organic chemistry have either omitted or deleted the preparation of chloroform. Preference has been given to experiments in which the products are obtained in good yields and in which comparatively inexpensive chemicals are used. In perusing the different laboratory manuals which contain the preparation of chloroform, one wonders why so many different methods are given for the preparation of the same compound. If these different methods are tried, some will give almost negative results. The variations in procedure are evidently given for the purpose of increasing the yield of chloroform. The low yield obtained by the student may cause him to doubt the value of the haloform reaction. Very satisfactory yields are obtained in the preparation of iodoform and bromoform and there is no reason why chloroform should not give as large a yield as these, provided the proper precautions are taken to avoid loss of so volatile a liquid.

Many laboratory books (*1*, *2*, *3*), call for the distillation of the product immediately after the addition of the alcohol or acetone, resulting in a mixture of alcohol or acetone and chloroform in the distillate. Adams and McElvain (*4*) shake the mixture until no more heat is evolved before distilling over the chloroform. Norris (*5*) uses steam distillation in the removal of chloroform from the reaction mixture. Cumming, Hopper, and Wheeler (*6*) call for the analysis of the calcium hypochlorite, as they claim that commercial bleaching powder is rather variable; the correct equivalent quantity should be taken from those results, otherwise poor yields are obtained. They add the acetone and distil off the chloroform directly. If alcohol is used instead of acetone, they suggest the passing of chlorine gas through the alcohol, forming chloral alcoholate. This is then mixed with bleaching powder and lime, the whole mixture heated, and the chloroform distilled over. Muldoon (*7*) refluxes the mixture thirty minutes before distilling over the final product. Porter, Stewart, and Branch (*8*) distil the chloroform over into ice water in an effort to prevent any loss of chloroform. Lowy and Baldwin (*9*) have recourse to H.T.H., a high-test hypochlorite containing approximately 65 per cent available chlorine. As ordinary bleaching powder as obtained from chemical warehouses or used in laundries contains only about 30 per cent available chlorine, they claim that the use of H.T.H. always tends to increase the

yield due to the large amount of chlorine present, and to the ultimate complete chlorination of the reagent used.

If alcohol is the reagent used, it must first be oxidized to acetaldehyde by the chlorine. Acetaldehyde is a very volatile liquid, and there is a possibility that some is lost at this phase of the reaction. The acetaldehyde must then be chlorinated to chloral (trichloroacetaldehyde) before decomposition by the calcium hydroxide can take place.

If a ketone is used, it must of necessity contain a methyl group, as does acetone, since the haloform reaction is possible only with compounds containing the acetyl group; the reaction is, in fact, a test for the presence of the acetyl group. Acetone, the ketone commonly used in this reaction, is a volatile liquid. The methyl radical of the acetyl group is first chlorinated, forming trichloroacetone, which is then decomposed by the bleaching powder to chloroform and calcium acetate.

Refluxing or distilling the whole reaction mixture at once seems to give a low yield, due principally to the volatility of the chloroform itself. Unreacted acetone also distils over, thereby lowering the yield of chloroform. There may also be a loss of acetaldehyde, if alcohol is used.

The solution to the problem seems to be to add the reagent slowly, and to distil the chloroform over as soon as it is formed, using as little heat as possible, thereby preventing a too rapid volatilization of chloroform and allowing a complete condensation of vapors by means of slow distillation. The method of preparing chloroform outlined below seems to overcome most of these difficulties, and it has worked without fail with students in elementary organic chemistry.

PREPARATION OF CHLOROFORM

Introduce into a one-liter round-bottomed flask a paste made by mixing 200 grams of bleaching powder (available chlorine—30 per cent) with 300 cc. of water. Add a small piece of paraffin wax, the size of a pea, to keep down excessive frothing. A "bumping tube" is then placed into the flask. This is made by sealing the end of a 5-mm. piece of glass tubing, and cutting to such a length that when the open end, which has been fire-polished, is resting on the bottom of the flask, the closed end is leaning against the neck of the flask about one inch below the stopper. The flask is then fitted with a two-hole stopper. A dropping funnel is inserted in one hole, the end of the funnel extending well below the surface of the mixture in the flask. Through the second hole is placed a piece of glass tubing bent at an angle. This is then connected to a water condenser set up for distillation. The end of the condenser is attached to a receiving flask by means of an adapter. The receiver is placed in a freezing mixture, such as ice and salt, or ice and hydrochloric acid.

Close the stopcock of the dropping funnel and introduce into it a mixture of 32 cc. of acetone and 32 cc. of water. Allow about 5 cc. of the acetone–water solution to enter the flask. Heat the flask gently, protecting the bottom of the flask with an asbestos or wire gauze. When frothy bubbles, which do not break immediately, rise to the surface, the reaction has begun. Withdraw the flame. The acetone–water solution can now be added slowly to the reaction mixture. If this is done carefully, the heat of the reaction will make the use of external heat unnecessary and there will be a steady condensation of chloroform. Frothing will continue as long as chloroform is being produced. When all the acetone–water solution has been added and the frothing has ceased, slowly bring the mixture to boiling and boil until the condensate is clear.

PURIFICATION

Separate the chloroform from the water. Add an equal volume of a 10 per cent solution of sodium hydroxide, shake, and allow to stand. Separate the two layers, run the chloroform into a small dry Erlenmeyer flask, and add anhydrous calcium chloride. When clear, pour the chloroform into a small dry distilling flask, and distil over a steam or hot-water bath into a dry container. Collect the portion which boils between 60°–62°.

YIELD

The yield of chloroform obtained by this method was so satisfactory that the preparation was given to students of organic chemistry in two different colleges. A total of ninety-one students prepared chloroform in this way with the following results: The average yield for the ninety-one students was 28.7 grams, or 54.87 per cent of the theoretical yield, which is 52.39 grams. The lowest yield obtained by any one student was 16.0 grams or 30 per cent of the theoretical. The highest was 40.86 grams or 78 per cent of the theoretical. The same preparation was given to advanced students in organic chemistry, and yields of 80–85 per cent of the theoretical were obtained.

The yields obtained by students in elementary organic chemistry seem high enough to warrant inclusion of this method of preparation of chloroform in any general course in elementary organic chemistry.

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Isotopes as Indicators

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THE indicator[1] applications of isotopes, once limited to a small number of naturally occurring radioelements, have assumed considerable importance since the discovery of artificial radioactivity and with the development of improved methods of concentrating stable isotopes. In view of the increasing interest being displayed in this type of investigation, especially in the biological sciences, it is perhaps timely to review the principles upon which such applications are based and to present a number of pertinent examples.

All such indicator experiments depend upon the use of some isotope, the properties of which permit its detection and measurement in the presence of other isotopes of the same element. This applies alike to stable and to radioactive isotope indicators, although the latter were employed long before the stable isotopes were available in convenient concentrations. In the case of radioelements, the measurement may require the aid of photographic plates, electroscopes, or counters; with stable isotopes, it is necessary to resort to properties[2] such as gas density or heat conductivity, specific gravity, or refractive index of water produced by combustion if oxygen or hydrogen isotopes are involved, or the mass spectrograph may be employed. Stable isotopes of the relatively light elements only can make good indicators because of the great analytical difficulties entailed in distinguishing between isotopes of high atomic weight. Indicators may be used in an isotopically pure form or mixed with other isotopes of the same element. With radioelements which are detected readily in unweighable quantities, pure isotopes are rarely employed. For stable elements, on the other hand, the analytical procedures are not so sensitive and require a higher concentration of indicator isotope; hence a relatively high concentration is the rule, and even isotopic purity (*3*) may be approached.

Investigations involving indicator isotopes may be divided into several general groups depending on the ratio of distinctive or marked or "tagged" indicator isotope to the ordinary form or forms. One class of applications results from the chemical inseparability of isotopes once mixed, *i. e.*, the isotope ratio remains constant throughout this type of experiment. A second type permits conclusions to be drawn from changes in this ratio, such as may be produced by an exchange or redistribution reaction. Finally there is a third group of investigations in which the ratio is immaterial; but examples of this class are of interest primarily to the biologist, and will not be discussed in great detail. Without pretending to present a complete survey of the field, examples will be cited of how isotopes, both active and stable, have been exploited to yield information of significance in chemistry.

THE ISOTOPE RATIO[3] REMAINS CONSTANT

The earliest indicator work (*1*) belongs to this group, in that an active lead isotope such as radium D or thorium B was mixed with ordinary lead so that the weight of element corresponding to a given activity was fixed. This radioactivity was then the means of performing a microanalytical determination for lead, since chemical processes are incapable of producing any appreciable change in isotope ratio. Thus the small amount of lead present in a saturated solution of lead chromate prepared from the original active solution was revealed by the radioactivity of this solution. Since the weight of lead corresponding to a given activity was known in advance, and the activity of a given volume was measured, the solubility, which was of the order of 10^{-7} molar, could be derived quite simply. Similar measurements of cobalt (*4*), phosphorus (*5*) and other lead (*6*) compounds have since been reported.

A second physical property determined by means of a radioelement is the exceedingly low vapor pressure (*7*) of thorium acetylacetonate measured by the gas saturation method. In this case, of course, the thorium itself is radioactive, and served as a measure of the minute quantities swept along by a stream of nitrogen.

Another potential microanalytical use of radioelements is as a check on the completeness with which small amounts of various elements can be handled. It is evidently possible to determine the limits of error in different analytical operations such as precipitation, electrodeposition, etc., as well as to correct for losses during the manipulation of small amounts of material. Hevesy and Hobbie (*8*) have made effective use of such a procedure in connection with a series of analyses of rocks for their lead content by adding a known amount of radium D immediately after solution of a sample, and then measuring the activity of the final form (lead peroxide in this case) in which the lead was recovered for

[1] This term was coined by Hevesy and Paneth in 1913 (*1*) in connection with the first use of radioactive isotopes in solubility measurements in which the properties of the radioelement were of secondary importance. Of late the term tracer element has come into use. It seems to the writer that this term should apply only to cases in which the isotope ratio remains constant or is immaterial.

[2] Detailed information concerning the preparation, concentration, and measurement of isotopes and isotopic mixtures may be found elsewhere (*2*).

[3] In dealing with radioactive substances, the quantity of active isotope is never expressed as an actual concentration, which is extremely small, but rather in arbitrary units of activity depending on the measuring device employed. These in turn are proportional to the quantity of radioelement present.

weighing. By comparing the initially added activity with that of the peroxide, any lead deficiency was revealed and could be corrected for.

With radioelements it has been possible to test a number of fundamental laws down to very small concentrations. Thus the mass action law, applied to the solubility of radium sulfate (*9*) in sodium sulfate solutions, was found to hold in 0.1 *N* solutions of the latter; and the validity of the Nernst electromotive force equation (*10*) was demonstrated down to 10^{-12} *N* with bismuth using thorium C as indicator. In view of the great sensitivity of detection of radioelements, it is not surprising that adsorption and coprecipitation studies have been made at exceedingly low concentrations (*11*).

Observations of certain chemical properties also have been facilitated by this ease of detection. The earliest examples are the experiments of Paneth (*12*), who proved the existence of polonium and bismuth hydrides. Furthermore, the alpha radiations from polonium, which is not available in weighable quantities, have permitted studies of the chemical properties (*10*, *13*) of this element.

Certain diffusion measurements also fall under this heading. By way of illustration, the diffusion of lead (*14*) into thallium may be cited. A lead foil, activated by thorium B, was pressed against a thallium foil, and the diffusion process followed by observing the growth in activity or increase in number of alpha-particle scintillations on the thallium side. By making these observations at time intervals, it was possible to calculate the diffusion coefficient without resorting to laborious analyses.

Corroborative evidence for the existence of an anomalous type of mixed crystals (*15*), in systems of non-isomorphous components such as lead and alkali halides, has been obtained by taking advantage of the effect of radioactive radiations on a photographic plate. A polished surface of the crystal is brought into contact with the plate for a time; and from photomicrographs made after development, it is possible to differentiate between "internal adsorption," which produces spotted exposure, and true incorporation of the lead ions in the alkali halide crystal lattice, which shows up as a uniform blackening of the plate within the boundary of the crystal. Such photographs have been called "radiographs."

The same photographic technic has revealed the existence of colloidal aggregates of atoms, termed radiocolloids (*16*), in solutions of certain radioelements despite the fact that the concentration of the element is insufficient to exceed the solubility product of any compound involved. This phenomenon occurs chiefly with isotopes (as thorium C) of elements (as bismuth) the salts of which are readily hydrolyzed. Similar radiographs have made visible the locale where certain elements concentrate during the formation and treatment of alloys (*17*), and have even served to identify an intermetallic compound (*18*) in the barium–zinc system. Radium, which, though not isotopic, is isomorphic with barium, was used as the indicator for the barium.

Only radioactive isotopes have been mentioned so far because this first group of applications depends on a sensitive method of analysis beyond the range of ordinary analytical chemistry. Obviously no analytical advantage is gained with stable isotopes by substituting one isotope for another.

THE ISOTOPE RATIO IS IMMATERIAL

Whenever the path and distribution of an element in a complicated system is of primary importance, regardless of the mechanism of the process, any variation in ratio of isotopic forms is immaterial. Thus if the phenomenon of self-diffusion is considered, only the local concentration of the marked or tagged isotope is of significance. Such measurements (*19*) have been performed for active lead, gold, and copper diffusing into ordinary lead, gold, and copper, for active lead salts into inactive salts, and for the liquid phase diffusion of deuterium into hydrogen (*20*). The radiograph experiments previously mentioned in which the concentration of certain elements in grain boundaries of alloys was revealed could well be included in this category.

Many examples of this group of applications are to be found in biological researches. Since isotopes allow a distinction to be made between that portion of an element, as phosphorus or calcium, which is newly introduced, and that which was in the system originally, it is obviously feasible to ascertain the distribution and to trace the path of practically all elements in plants and animals. Although these metabolism studies are of great interest, they cannot be discussed here. Surveys of such work can be found in the literature. They involve the use of radioactive indicators (*21*) such as active phosphorus, calcium, sodium, iron, iodine, and many other artificial radioelements, as well as stable isotopes (*22*) of oxygen, nitrogen, hydrogen and potassium.

THE ISOTOPE RATIO CHANGES

By taking into account both the indicator and the total isotope concentrations, it is possible to gain considerable insight into the mechanism of chemical processes as well as the relative strength and equivalence of chemical bonds. Let us illustrate this contention first with single-phase systems. An exchange of bromine atoms between radioactive hydrogen bromide and bromine (and vice versa) in the gas phase has been found (*23*) to occur rapidly at room temperature. The reaction may be written[4]

$$H\overset{*}{Br} + Br_2 = HBr + \overset{*}{Br}_2$$

and could have been demonstrated only by the isotope indicator technic. Judging from the rapid rate at

[4] "The asterisk indicates a radioactive atom. $\overset{*}{Br}_2$ means that one of the bromine atoms is radioactive.

which the bromine became radioactive, the reaction seems to proceed by a chain mechanism involving bromine atoms. A photosensitized exchange of hydrogen atoms between methane and molecular hydrogen, demonstrated (*24*) by means of deuterium, illustrates the use of a stable indicator. This reaction was followed with the aid of infra-red absorption measurements.

A great many liquid phase exchanges have been reported. They deal with oxidation-reduction reactions as well as with others, ionic and molecular, in which no valence change takes place. We find (*25*), for example, that radioactive bromine will distribute itself completely between ethyl bromide and dissolved aluminum bromide in about one minute, showing that the bromine atoms in the latter compound are equivalent as regards reactivity. The criterion for complete exchange is that the ratio of active to inactive isotope shall be the same in all components of the system. In other words, at exchange equilibrium the activity of a component should be proportional to the quantity of inactive isotope it contains. In apposition may be mentioned the examples of sodium thiosulfate (*26*) and cupric bromide (*27*) in which the sulfur and bromine atoms were shown by radioactive indicator experiments to be of unequal reactivity. By comparing the rate and extent of exchange of halogen between active sodium iodide (*28*) or aluminum bromide (*25*) and various halides, the greater strength of the aromatic over the aliphatic halogen bond is brought out clearly. The resistance to a redistribution of iodine, which would have resulted in the incorporation of radioactive iodine in the organic molecule, was greater for the aromatic compounds.

A more intimate knowledge of the mechanisms of a number of organic reactions—as the Hoffman (*29*) and Walden (*30*) rearrangements for example—has been obtained by the use of active halogens. Recently Calingaert (*31*) and his collaborators have reported a statistical redistribution of organic radicals between organo-metallic compounds, this random interchange being catalyzed by a wide variety of metal halides and alkyl metal halides. To ascertain whether the catalyst likewise was capable of participating in such an exchange, an equimolecular mixture of radioactive tetraethyl lead and inactive catalyst triethyl lead chloride was prepared, and the activities of the components measured at various time intervals. It was found that within twenty-four hours both compounds had become equally active, proving not only that this particular catalyst at least played an active role in the reaction, but that the chlorine atoms as well as the ethyl groups had taken part in a rapid interchange between the lead compounds. This reaction may be represented as

$$Et_4\overset{*}{Pb} + Et_4PbCl = Et_3\overset{*}{Pb}Cl + Et_4Pb$$

A number of inorganic exchange reactions involving ions of phosphorus (*32*), arsenic (*33*), and manganese (*34*) have been studied. No significant exchange is manifest in mixtures of $\overset{*}{P}O_4^{-3}$ and PO_3^{-3}, or of AsO_4^{-3} and $\overset{*}{As}O_3^{-3}$, in either alkaline or acid media at boiling temperatures. In the case of the arsenate–arsenite equilibrium, addition of iodine and hydrochloric acid permitted the exchange to take place. This was utilized to measure the rate of the oxidation-reduction reaction

$$H_3AsO_3 + I_3^- + H_2O = H_3AsO_4 + 3I^- + 2H^+$$

at equilibrium since the velocity of the reaction

$$\overset{*}{As}O_3^{-3} + AsO_4^{-3} \rightarrow AsO_3^{-3} + \overset{*}{As}O_4^{-3}$$

could be measured despite the fact that no appreciable overall concentration changes were possible under the experimental conditions. This exchange reaction obviously represents the rate of the reversible oxidation of arsenite.

There is no lack of exchange reactions involving stable isotopes in liquid media. Thus the exchange of O^{18} between water (*2e*) and a large number of organic compounds such as acids, aldehydes, ketones, etc., has been demonstrated; and inorganic substances such as sulfates, phosphates, carbon dioxide, and sulfur dioxide undergo a similar reaction. To illustrate the use of deuterium, mention may be made of the hydrogen–deuterium exchanges which occur between esters (*35*) and deuteroalcohol or between many organic substances (*36*) and heavy water. Stable isotope indicators have been used also in studying the mechanism of organic reactions such as ester hydrolysis, polymerization, and esterification. Polanyi (*37*) employed H_2O^{18} in the saponification of amyl acetate to prove that the bond which broke during this reaction was between the AmO— and the CH_3CO— groups instead of adjacent to the amyl radical. This followed from the absence of additional heavy oxygen in the amyl alcohol formed. Had the split involved simply the alkyl radical, the O^{18} would have been incorporated in the amyl alcohol.

Exchange reactions are not limited to homogeneous systems. Bromine atoms are found to distribute themselves between gaseous radioactive bromine and silver bromide (*38*); and they will do likewise (*25*) between either liquid or solid aluminum bromide in contact with hydrogen bromide or free bromide. Exchanges in the gas phase can be induced catalytically. In the presence of oxide (Mn, Fe, Cr, etc.) catalysts, O^{18} will exchange (*39*) between gaseous oxygen and heavy water vapor. Metals will catalyze (*40*) a deuterium–hydrogen interchange between deuterium and hydrocarbons, while an N^{14}–N^{15} exchange occurs (*41*) in mixtures of light and heavy nitrogen at the surface of iron synthetic ammonia catalysts and tungsten filaments. The latter reaction takes place readily only above 450°, which stands in marked contrast to the ready exchange (*3*) of hydrogen isotopes on chromium oxide and nickel at temperatures as low as −190°. The importance of such indicator studies in the field of catalysis is obvious.

A most interesting application of an isotope exchange at the solid–liquid interface involves the determination of the specific surface (*42*) of crystalline powders. As-

suming that the exchange is restricted to the surface of a powder, such as silver chloride immersed in a solution containing radioactive sodium chloride ($Na\overset{*}{Cl}$), it follows that the ratio of the adsorbed to unadsorbed indicator isotope $\overset{*}{Cl}$ will be equal to the ratio of chloride ions at the surface to the number of chloride ions dissolved. Since this ratio is readily obtained by comparing the initial and final activities of the salt solution, and the amount of dissolved chloride can be regulated, the specific surface follows directly from the expression

$$Sp.\ Surf. = \frac{\overset{*}{Cl}_{ads.}}{\overset{*}{Cl}_{left}} \frac{(Cl^-)_{soln.}}{\text{wt. AgCl}}$$

The specific surfaces of a large number of lead salts (*42*, *43*) and of silver halides (*44*) have been measured by this method of Paneth. With fresh precipitates (*45*), the value so obtained is extremely large, but diminishes rapidly, thereby revealing aging processes which are not restricted to external surfaces. They appear also to involve those ions which are at the interior of microscopically visible particles.

This discussion will be concluded by citing an investigation which illustrates an interesting metal catalyzed stable isotope exchange between the gas and liquid phases. Polanyi (*46*) and co-workers have observed a hydrogen–deuterium interchange between molecular hydrogen (heavy) and liquid benzene at room temperatures, catalyzed by platinum black and nickel. This exchange is surprising because it is not accompanied by a simultaneous hydrogenation of the benzene.

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Concerning Lantern Slides

Teachers are reminded that Dr. H. N. Alyea of Princeton University is offering copies of 400 filmslides at cost ($5.00), as announced in the November issue of this JOURNAL, page 546. Orders received within the next few weeks will be filled immediately.

Graphical Correlation between pH Values, Molarities, and Dissociation Constants of Weak Acids

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IN THE course of studies on the production of various organic acids through the fermentation of glucose by fungi and bacteria (*4, 11*), it has been found desirable to show the approximate relationships of various constants for certain acids, as well as their comparative strengths. This information was available partly from the dissociation constants, partly through calculation for the specific acids, and from analyses of samples at various concentrations. In order to avoid frequent calculations, curves for the various acids were prepared and a few were assembled in Figure 1. The plotted values of this graph show the relationships that exist in pure solutions between pH, molarity, and the dissociation constant. A scale for pK, the logarithm of the reciprocal of the dissociation constant, has been included.

The pH values for each acid solution were obtained through the use of the formula:

$$pH = \log \frac{1}{(H^+)} = \log \frac{2}{-K + \sqrt{K^2 + 4KM}}$$

where (H^+) = concentration of the hydrogen ion, K = dissociation constant, and M = molarity of the solution. This formula was derived from the mathematical expression of the dissociation constant:

$$\frac{(H^+) \times (A^-)}{(HA)} = K$$

By means of this formula, the pH values at 25°C. were calculated for the various molarities.[2] It should be pointed out that the calculated pH value thus obtained is a function of the concentration or dissociation constant and the molarity and is approximated by the value obtained by and defined in terms of a glass electrode assembly and some standard calibrating solution. Hirsch and Schlays (*5*) reported the dissociation constant for glucose as 7.8×10^{-13} at 25°C. May, Weisberg, and Herrick (*10*) obtained for *d*-gluconic acid the average constant of 1.65×10^{-4}. Values for hydrochloric acid solutions are those adapted by Buchanan and Fulmer (*1*) from the experimental data of Randall and Young (*12*). Hydrochloric acid was plotted on the graph in order to show the relative position of a strong mineral acid. The other dissociation constants were obtained from the handbooks of Lange (*8*) and Hodgman (*6*).

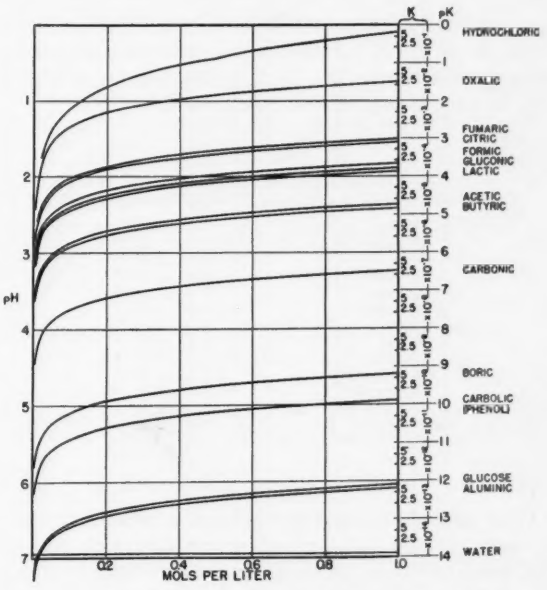

FIGURE 1.—GRAPHICAL RELATIONSHIPS BETWEEN pH VALUES, MOLARITIES, AND DISSOCIATION CONSTANTS, INCLUDING pK, FOR SOME ACIDS AT 25°C.

Variations in temperatures will cause changes in the plotted values. Kraus (*7*) reported a decrease in ionization with increasing temperature and Buchanan and Fulmer (*1*) stated that a rise in temperature increases the conductivity of solutions of electrolytes The decrease in viscosity accompanying a rise in temperature increases conductance and thereby causes an apparent increase in hydrogen-ion concentration which is measured as a decrease in pH. At infinite dilutions the pH–molarity curves should approach the value of pH 6.95, the pH of water at 25°C. which was determined by Lorenz and Böhi (*9*) and W. M. Clark (*2*). The use of the formula appears to give erroneous results for very dilute solutions of glucose and aluminic acid,

[1] Established by the Bureau of Agricultural Chemistry and Engineering, U. S. Department of Agriculture, in coöperation with the Iowa State College.

[2] The authors wish to include the following comment made by JOURNAL reviewers:

"For . . . molarities above 0.1 and for values $K_e \gtrsim 10^{-4}$ (or, in general, for all values of $M/K \leq 10^3$) equally precise values of pH (within 0.01 unit) may be obtained by the use of the simple formula $pH = -\log \sqrt{KM}$ as by that of the more complicated approximation which they (the authors) used.

"The shorter formula, in the form $pH = \frac{pK + pM}{2}$ lends itself to the construction of a particularly simple form of nomogram, or a plot of pH against log M on which the curves for all acids are straight lines."

yet in spite of such incongruities the graph retains its practical significance. These anomalies (the extension of the curves below the pH line for water) may be the result of disregarding the effect of dissociation of water. Continuation of the curves to approach the value of pH 6.95 has not been plotted in order to avoid confusion in reading the graph. Values at other temperatures may be obtained through the use of Fulmer's nomogram (*3*).

In the cases of the acids shown (oxalic acid excepted) the curves of the pH values (calculated from dissociation constants given in Table 1) meet the one-molar ordinate at the K values equivalent to their respective dissociation constants. It is interesting to note that the K scale is logarithmic within each unit.

TABLE 1

DISSOCIATION CONSTANTS OF VARIOUS ACIDS AT 25°C.
(From Hodgman (*6*) and Lange (*8*) except where indicated)

Acetic	1.86×10^{-5}
Aluminic	6.3×10^{-13}
Boric	6.4×10^{-10}
Butyric	1.48×10^{-5}
Carbolic	1.3×10^{-5}
Carbonic	3.0×10^{-7}
Citric	8.0×10^{-4}
Formic	2.14×10^{-4}
Fumaric	1.0×10^{-3}
Gluconic (*10*)	1.65×10^{-4}
Glucose (*5*)	7.8×10^{-13}
Lactic	1.38×10^{-4}
Oxalic	3.8×10^{-2}

APPLICATIONS OF THE GRAPH

The dissociation constant (K) of a weak acid being known, the pH value at molar concentration and the pK equivalent can be approximated by the position of K on the one-molar ordinate; for example, fumaric acid, having a dissociation constant of 1×10^{-3}, will have a pH value of 1.5 and a pK equivalent of 3.

Curves for acids not given in this graph may be approximated. Observation shows that for any two acids the curves are nearly equidistantly apart between the concentrations of 0.05 and 1.0 molar. As an example, carbonic and butyric acids may be chosen as the reference and unknown acids, respectively. The distance between the dissociation constants of those two acids on the one-molar ordinate will then be the distance between the pH curves at corresponding molarities, so that for any given molarity the pH of the second acid, butyric, can be readily determined. If the pH and corresponding molarities of an acid are known, its dissociation constant and pK may be readily approximated from such a graph.

This method of presenting various acid constants provides a means of indicating apparent acidity or "sourness" of various acid solutions of equivalent molarity, the apparent acidity decreasing from the top toward the bottom of the graph. Thus, hydrochloric is the most active of the acids plotted and aluminic is the least active.

Such a group of curves may be applied in fermentation studies; knowing the pH and molarity of a liquor, the acid of maximum apparent activity in the solution may be indicated from the graph. Thus, in the conversion of glucose to gluconic acid by Acetobacter (*11*), a liquor with an acidity of pH 2 in approximately 0.6 molar solution indicated that the predominant portion of the acid mixture is probably gluconic. This was verified by quantitative analyses. At the same concentration, lower pH values would indicate the presence of acids more active than gluconic, while higher values would indicate the probable absence of this acid. The approximate amount of glucose necessary to produce a concentration of acid of any desired pH may be determined by means of such a graph. The activity of some microörganisms is inhibited below specific pH values, hence acidification offers a means of preventing the growth of some contaminants. The graph may aid in the selection of an acid to give the desired pH value.

This graph corroborates the order of successive neutralizations in the conductometric titration of a mixture of acids as reported by Whittemore, Reid, and Lynch (*13*), these neutralizations occurring in the order of decreasing ionization constants. Displacement of acid radicals from their salts can be predicted from a study of such a graph, an acid of relatively high activity displacing the radical of an acid of lower activity. This fact aids in the preparation of organic acids from their salts by a suitable strong acid. The solutions are adjusted to the proper pH by varying the salt or acid concentration.

A comparison of the pH values of a few organic acids as calculated from the formula and as determined with a glass electrode is presented in Table 2. As the pH of a solution is affected by variations in temperature, the observed readings were corrected to 25°C. by means of Fulmer's formula (*3*) and are fairly close to the pH as calculated from the constants or read from the graph. In the given mixtures of acids, the pH value of the mixture appears to be that of the acid that liberates the greatest amount of hydrogen ions; for example, a 0.0341 molar solution of oxalic acid has a

TABLE 2

COMPARISONS OF THE pH OF A FEW ORGANIC ACIDS AND COMBINATIONS OF ACIDS AS CALCULATED FROM KNOWN CONSTANTS AND AS DETERMINED ELECTROMETRICALLY

Acids Used	*Concentration as Molarity*	*pH Calculated from Constants at 25°C.*	*pH Observed at Indicated Temperatures, °C.*	*Observed pH Corrected to 25°C.*
Acetic	0.8340	2.41	2.40 (29°)	2.47
Acetic	0.0998	2.87	2.84 (29°)	2.91
Formic	0.9830	1.84	1.83 (27°)	1.86
Formic	0.1351	2.28	2.31 (27°)	2.34
Oxalic	0.1937	1.16	1.13 (29°)	1.20
Oxalic	0.1023	1.34	1.23 (29°)	1.30
Citric	0.2161	1.89	1.86 (27°)	1.89
Citric	0.1051	2.06	2.03 (27°)	2.06
Acetic	0.4670*	2.53	1.63 (29°)	1.66
+				
Citric	0.4689*	1.72		
Formic	0.6553*	1.93	1.53 (29°)	1.56
+				
Oxalic	0.0341*	1.66		

* These values indicate the concentration of the individual acids in the mixture.

greater concentration of hydrogen ions or lower pH value than does a 0.6553 molar solution of formic acid.

The most satisfactory use of such a group of curves is obtained when plotted on a large scale in order that the intermediate values may be found with greater accuracy. As Figure 1 presents the curves of only a few acids, it is suggested that the investigator plot curves for the acids with which he is concerned.

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An American Pioneer in Nutrition and Digestion[1]

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MY CURIOSITY was very much aroused when I came across the following statement,[3] "The first American investigation on the subject of human nutrition .... was carried on by J. R. Young in Philadelphia in 1803." Most of us labor under the impression that Dr. William Beaumont was by far the earliest American worker in this field. He began his work in 1825 and published his findings in 1833, in a book entitled, "Experiments and Observations on the Gastric Juice and the Physiology of Digestion." The story is well known to scientists in the various branches of medicine and need not be related here. Much has been written about his work.

The investigation referred to by the above quotation is entitled, "An Experimental Inquiry into the Principles of Nutrition and the Digestive Process." To say the least, the two titles give one the impression that the studies covered very similar lines, as indeed they did. After some search several copies of Dr. John Richardson Young's thesis were located. It proved to be an inaugural dissertation of the University of Pennsylvania, as a part requirement for his medical degree. Much importance was then attached to the publication of these independent researches by the Medical School of the University. Its library contains hundreds of them.

This young physician was born in 1782, obtained his baccalaureate degree from the College of New Jersey, later Princeton University, in 1799, his medical degree in 1803, and died in 1804. The work was done, therefore, while a student, before he reached his majority. Notwithstanding his youth, this investigation is most interesting, original, ingenious and of far-reaching importance. The early death of the author and the obscurity of the publication of his thesis probably account for the little attention given to this remarkable research on nutrition and digestion. But for this thesis his name would have been forgotten. It is his one claim to fame. One naturally wonders why the work of this young genius was not given some consideration by the famous world scientists who attended the Thirteenth International Congress of Physiologists in Boston in 1929, during which gathering such signal honors were accorded Dr. Beaumont. The frog certainly has proven to be a useful experimental animal during the intervening years. The author in a beautiful tribute dedicated his thesis to his father-preceptor, Dr. Samuel Young. It is also inscribed to Benjamin Smith Barton, M.D., because of his eminent skill in his profession and for the many favors granted him. On page one is a quotation from Antoine L. Lavoisier which

[1] Presented before the Division of the History of Chemistry at the ninety-seventh meeting of the A. C. S., Baltimore, Maryland, April 5, 1939.

[2] Former government specialist in foods, drugs and cosmetics.

[3] Bulletin No. 80, Office of the Experiment Station, U. S. Department of Agriculture, Washington, D. C., 1900, p. 106.

reads, "We ought in every instance to submit our reasoning to the test of experiment and never search for truth, but by the natural road of experiment and observation."

The revolution wrought in chemistry by Lavoisier and his cruel, untimely death stirred the scientific world then and for years thereafter. His system of chemistry was rapidly gaining a footing in the United States. The young student's professors of chemistry, John Maclean of the New Jersey College and James Woodhouse of the Medical School of the University of Pennsylvania, were both disciples of Lavoisier. It was probably from these teachers that he obtained his first knowledge of Lavoisier's classic work in chemistry and his establishment of the modern system of metabolism. He probably became acquainted with the controversies between his instructors and other American chemists and the eminent Joseph Priestley on the subject. Priestley was a staunch phlogistonist and an opponent of the French chemist's system.

While engaged in his medical studies he probably also came into personal contact with such additional prominent scientists as Adam Seybert, John R. Coxe, Robert Hare, Benjamin Rush, Benjamin Silliman, Samuel Cooper, Caspar Wistar, Charles Caldwell, and others who either lived or studied at the time in Philadelphia, then the scientific center and the largest city in the United States. The Philadelphia Chemical Society, the first chemical society in the world, was then in a flourishing condition and brought many distinguished scientists to its meetings. Certainly it was a wonderful environment in which a young man might receive an education.

Several brief sketches of John R. Young are in print.[4] The reader is referred to them for generalities. The object of this article is primarily to call attention to some of the unique features of his investigations. Nutrients he described as substances taken into the system, suited to supply material for growth and waste of solids and fluids—a pretty good definition, even one and a third of a century later. Oils and sugar he considered the principal articles of diet. Reference is made to Dr. Wm. Stark living on olive oil and flour (bread) for fourteen days and gaining over four and a half pounds. Bones, he noted, are subject to constant waste and require calcareous material for repair. The utility of water and oxygen in life is interestingly discussed.

Dr. Wm. Stark (1741–70) made[5] extended digestion experiments on himself, a third of a century before Dr. Young entered the field—the earliest experiments of the kind recorded. The studies covered both simple and mixed foods. Among them may be mentioned milk, olive oil, bread, eggs, butter, beef, sugar, suet, goose meat, and marrow. These early experiments are seldom referred to in either dietetic or nutritional literature, but Dr. Young evidently studied them. It is alleged that Dr. Stark shortened his life by excessive experimenting on himself. A number of other workers in nutrition and digestion antedated the work of Dr. Young. The best known are René A. F. Réaumur, George L. L. Buffon, Lazaro Spallanzani, and Antoine L. Lavoisier. All of these and others are referred to by the young medical student.

Dr. Young carried out his experiments with bullfrogs, snakes, and on himself, but the bullfrog (*Rana ocellata*) was the chief experimental animal. Why this cold-blooded animal was selected may be judged in part from some of the comments in the thesis. The value of the frog as a test animal was then foremost in the minds of scientists, because of the report by Luigi Galvani that electricity causes the contraction of the muscles of a dead frog. Furthermore, the bullfrog is carnivorous, swallows his food whole, does not bite and, like man, has a membranous stomach, which can be easily reached and emptied through a capacious mouth and an accommodating gullet. The embryo doctor tells about removing the stomach contents of two bullfrogs. In one he found the remains of two spring frogs with the soft parts more or less digested. The bones were soft and flexible. The second frog's stomach contained a mouse, more or less digested, including the teeth. This was useful information. It showed that the gastric juice of bullfrogs acted on muscular tissue, bones, and even teeth. It undoubtedly influenced the course of some of his experiments.

Being desirous of knowing what length of time it would require a bullfrog to digest a small frog, he tied a pack thread to the hind legs of a living spring frog and caused a bullfrog to swallow it, which he readily did. After five hours he withdrew the spring frog, found it dead, and the external surface materially acted on; introduced it again for seven hours and on withdrawal found the abdominal muscles dissolved and the bones of the feet soft; he then caused the remains to be swallowed a third time and after six more hours a withdrawal disclosed that the texture was lost and only a part of the legs could be brought up. Many similar experiments were carried out, covering frogs, beef, and veal, always with the same results. He tried the same experiments with snakes, with the same results, except that snakes dissolved their food only about one-half as rapidly as the bullfrogs. He repeatedly removed the gastric juice from the stomachs of the bullfrogs by means of a small spoon and always found it acid to litmus paper. The young physician also found that the gastric juice of man and that of the bullfrogs and snakes agreed in their action on flesh. Heat or warmth was found to be a potent factor in effecting solution. This confirmed the earlier findings of the genius, Spallanzani, regarding the action of gastric juice. The latter made some unique gastric digestion experiments by swallowing hollowed-out blocks, filled with meat, and after a time regurgitated them, by tickling his throat. The object was to find out to what extent the gastric juice digested the meat inside of the hollow blocks. This torture he continued until he became so nauseated that he was forced to stop these experiments. Dr.

[4] KELLY AND BURRAGE, *Am. Med. Biog.*, (1920).
[5] SMYTH, "The works of the late William Stark," (1788).

Young conducted gastric digestion tests on himself. One consisted in swallowing the condyles (joint ends) of the thighs of a chicken. At the end of three days they were removed and found to be reduced to mere shells.

The experiments proved that the gastric juice of the bullfrog dissolves the tissues of a lifeless or dead frog, but will it dissolve live tissue or the tissue of a living frog? To prove this point Dr. Young introduced the spring frogs' hind legs first into the alimentary tract of bullfrogs, leaving their heads and forefeet just outside of the big mouth. The spring frogs held on with their forefeet. The frogs were kept in this position for one and one-half days, then withdrawn, and found to be covered with gastric juice, but perfectly alive and not dissolved in any part. These ingenious experiments left no reasonable doubt in the matter of the gastric juice of the bullfrog not dissolving living tissue. They also serve to explain why the walls of the bullfrog's stomach are not dissolved by its gastric juice. They likewise supply presumptive, if not conclusive evidence, why the gastric juice does not dissolve the walls of the living human stomach.

Lazaro Spallanzani was one of the cleverest and most ingenious investigators. His experiments will maintain a footing among the learned as long as experimental philosophy lasts, but Dr. Young questioned his views regarding the inability of carnivora to digest vegetable matter. In order to test the point of difference he introduced small linen bags, with strings attached, containing bread, whole wheat, beans, and peas, into the purely carnivorous stomachs of bullfrogs. At the end of thirty hours, the bags were withdrawn. It was noted that the wheat, beans, and peas were not acted on, but the bag that contained the bread was quite empty. The bags containing the seeds were again introduced and allowed to remain three additional days, when they were withdrawn and all found quite swollen, but intact. The bags with the beans, peas, and wheat, well bruised, together with some bread, were again introduced into the stomachs of bullfrogs and withdrawn at the end of two days. All of the bags were then found to be empty. The conclusions to be drawn are self-evident. The entire live seeds resist the action of the gastric juice of bullfrogs, but carnivora can and do digest unprotected vegetable seed substances. Other beans and wheat seeds were introduced in linen bags and when withdrawn at the end of six days were found to be swollen and soft. These same seeds were again introduced and at the end of six more days it was found on withdrawal that germs protruded from both the beans and the wheat. These experiments give support to the observation made by Morgagni, the anatomist, namely, that a young woman suffering with gastritis, during a violent spell of nausea, vomited a small plant with perfect leaves and roots.

Our young investigator also reported finding an acid condition present in all stomachs examined, both man and other animals, carnivorous and otherwise. This acidity he found was not due to either vinous or acetous or other fermentations, but had its origin in the stomachs themselves and was a part of the gastric juice itself. Having traced the acid to its origin, the next step was to ascertain its nature. After a series of tests he came to the conclusion that it was phosphoric acid. This, of course, was an error.

Some of my scientific friends, to whom I have related the experimental work of Dr. Young, can hardly credit it and think it is just a fantastic tale.

A careful study of Dr. Young's thesis leads to the inevitable conclusion that his findings in many particulars anticipated those of Dr. Beaumont by more than twenty years. It is true the former were carried out largely with bullfrogs, cold-blooded animals, while the latter were made with man, a warm-blooded animal. But in other respects the experiments and the results were closely paralleled. Dr. Young must be given the credit of being the American pioneer in studying nutrition and digestion.

In concluding this paper I believe it is desirable to call attention to certain interesting features and misfortunes of the Young family. The father, Dr. Samuel Young, was born in Ireland, 1730, educated in Trinity College of Dublin and the Medical School of Edinburgh. He, therefore, like his son, had a splendid education. He came to America before the Revolutionary War, practiced medicine in Elizabethtown, where the son was born, near Hagerstown, Maryland. The father apparently did not actively participate in the conflict of the continental army. He is not listed among the "Medical Men of the Revolution," 1876, by James M. Toner. The services of well-trained physicians were needed by both the home folks and the army during those trying times. The elder physician died in 1838, one hundred eight years old. Ann Richardson Young, the mother, of whom little seems to be recorded, died of pulmonary tuberculosis at the age of thirty-one, leaving, besides her husband and son, two daughters, one eight and the other six.

After receiving his medical degree, the brilliant son joined his father in the practice of medicine. He was then in frail health. A deadly disease was eating away his vitals. The partnership was terminated within one short year. The great white plague took his life. What the world lost in the death of this young genius can only be predicated on his accomplishments of a few short years as a student. His two sisters died of the same disease. So did another young physician who affiliated himself with the elder Dr. Young. It is most remarkable, to say the least, that the father, living in a tuberculosis-infected environment and necessarily inhaling and swallowing myriads of tuberculosis germs, lived to the unusual age of one hundred eight years. His resistance to this disease must have been most remarkable. One naturally wonders why some of this was not to some degree at least transmitted to some one of his children.

The Three-Component System Sodium Bromide–Hydrogen Bromide–Water

An Experiment in Elementary Physical Chemistry

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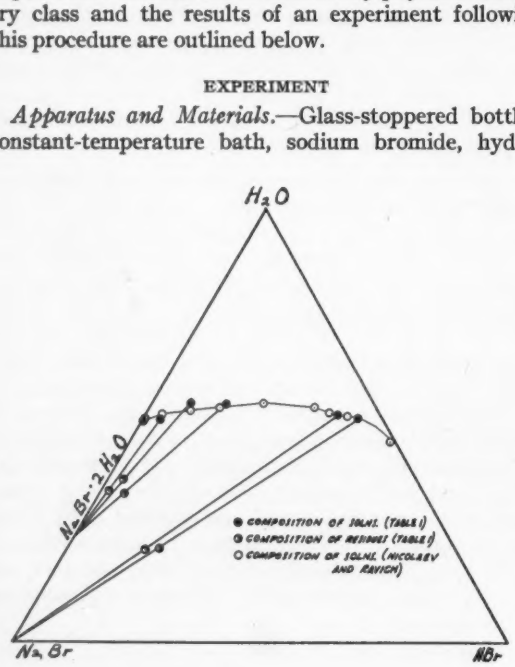
IN A previous paper (*1*), the system potassium chloride–hydrogen chloride–water was suggested as an elementary physical chemistry experiment on a three-component system containing two electrolytes with an ion in common. It was shown that by means of this experiment the wet residue method (*2*) of determining the composition of the solid phase in equilibrium with saturated solutions could be demonstrated. However, the fact that the solid phase in equilibrium with the saturated solutions in this system is so obvious makes the experiment somewhat lacking in interest. Consequently, it seemed desirable to work out an experiment for the introductory physical chemistry course, on a system of this kind, in which the composition of the solid phase is not so evident. The system sodium bromide–hydrogen bromide–water suggested itself as a possibility, since it has been shown in several studies (*3*, *4*, *5*, *6*) that sodium bromide exists as the dihydrate in aqueous solutions of hydrogen bromide at lower concentrations, and that at higher concentrations of the acid the solid phase becomes the anhydrous salt. A procedure suitable for an elementary physical chemistry class and the results of an experiment following this procedure are outlined below.

EXPERIMENT

Apparatus and Materials.—Glass-stoppered bottles, constant-temperature bath, sodium bromide, hydrobromic acid, 0.2 *N* silver nitrate, 0.1 *N* sodium hydroxide, phenolphthalein, potassium chromate.

Procedure.—A series of hydrobromic acid solutions are prepared by diluting a concentrated solution. About 50 cc. of each of these solutions are placed in glass-stoppered bottles, and slightly more sodium bromide than is required to saturate the solutions at about 30° is added. The bottles are then placed in a constant-temperature bath regulated at 25° and allowed to remain there for at least 24 hours in order to establish equilibrium between the solid and solution phases. Longer periods of time increase the probability of obtaining good results. It is suggested that the solutions be prepared at the beginning of one laboratory period and be left in the constant-temperature bath until the next period. The solutions should be shaken vigorously from time to time. Automatic stirring or shaking is, of course, desirable, but for the purpose of this experiment it is not essential if the 24-hour period is taken.

When equilibrium is established at 25°, approximately one-gram samples of the solution and residue are taken from each bottle and analyzed for hydrobromic acid by titration with sodium hydroxide, and for total bromide by titration with silver nitrate (*1*). From these titrations the per cent by weight of hydrogen bromide and of potassium bromide in the solutions is calculated.



TYPICAL RESULTS

In Table 1 are given the results of an experiment in which the above procedure was followed. The hydrobromic acid solutions were obtained by diluting a constant-boiling mixture prepared in the laboratory, the hydrogen bromide being made by the catalytic union of the elements. The two most concentrated solutions became slightly yellow when the sodium bromide was added (*5*); the others remained colorless. The sodium bromide was of U.S.P. quality. The constant-temperature bath was regulated at 25° ± 0.02°.

TABLE 1

Composition of Solutions		*Composition of Residues*		*Solid Phase*
% NaBr	*% HBr*	*% NaBr*	*% HBr*	
48.63	0.00			$NaBr{\cdot}2H_2O$
44.41	3.79	64.1	1.6	$NaBr{\cdot}2H_2O$
37.37	7.39	59.48	3.23	$NaBr{\cdot}2H_2O$
32.49	14.08	60.92	4.86	$NaBr{\cdot}2H_2O$
8.75	38.29	62.9	15.96	NaBr
4.95	43.38	60.07	20.02	NaBr

These results are also shown graphically in the figure. The data of Nicolaev and Ravich (*4*) on the composition of the solutions are also included in this figure as a means of comparison. It is evident that the results are sufficiently accurate for the purpose. The experiment has also been performed using commercial hydrobromic acid of various degrees of purity with fairly good results; even with one shelf-worn sample of the acid that had become brown in color the results were passable. Excellent results were obtained in another experiment in which this brown solution of acid was purified by distillation from anthracene.

Since the experiment indicates the transition from one solid phase to another, and since the average student in the beginning physical chemistry course does not always remember that sodium bromide forms the dihydrate, it is believed that it provides more interest than the previously mentioned experiment, and that it illustrates more fully the value of the wet-residue method.

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(2) See ref. (2) in the paper cited above.
(3) MELLOR, "A comprehensive treatise on inorganic and theoretical chemistry," Longmans, Green and Co., New York City, 1922, Vol. II, p. 532.
(4) NICOLAEV AND RAVICH, *J. Gen. Chem.* (U. S. S. R.), **1**, 785–91 (1931).
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A Spring Pendulum Current Interrupter for a Magnetic Stirrer

With Application to an Experiment in Catalysis

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IT IS the policy in our laboratory to introduce labor-saving apparatus for class use whenever feasible. In this connection, it was desired to construct a shaking apparatus for use in the experiment on the catalytic decomposition of hydrogen peroxide, described in the laboratory manual by Daniels, Mathews, and Williams,[1] since hand shaking of the reaction mixture proved to be tiresome and not very efficient. Reciprocating type shakers which were tried did not work well, so a magnetic stirrer was used which has proved very satisfactory. The use of magnetic stirrers is of course common knowledge, but the current interrupter we use is of our own invention and design, and it is thought that it may be sufficiently useful to warrant description.

The interrupter is a spring pendulum, itself actuated by a magnet to prevent damping out of its oscillations. A diagrammatic representation of the pendulum and wiring is shown in Figure 1. The two contacts *P* are for the pendulum magnet *PM* and *S* is the contact for the stirrer magnet *SM*. At each extreme of its oscillation the iron bob on the pendulum is pulled back to the center by the pendulum magnet, while at one extreme contact to the stirrer magnet is made. Construction of the interrupter could be simplified if contact to the stirrer magnet were made at both extremes, but if this were done the oscillation frequency would have to be so low as to require a clumsy length of pendulum.

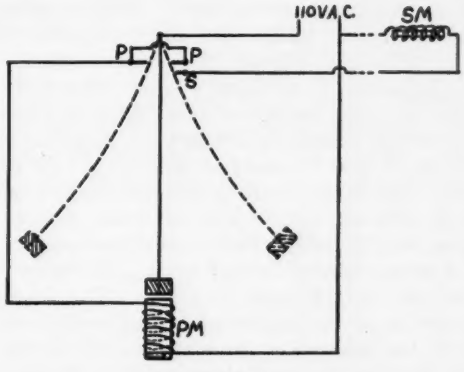

FIGURE 1

The perspective drawing (Figure 2) shows the general features of the apparatus as finally constructed. The base is wood, $^3/_4'' \times 5'' \times 7''$. The support rod for the pendulum and contacts is made from $^1/_4$-inch copper rod, 10 inches long, threaded at the lower end for bolting to the base. The horizontal part of the support for the pendulum and contacts consists of two pieces of 20-gage brass plate, $^1/_2'' \times 3^1/_2''$, with one end rounded, as in Figure 2, *A*, to fit around the support rod. Two 20-

[1] DANIELS, MATHEWS, AND WILLIAMS, "Experimental physical chemistry," 2nd ed., McGraw-Hill Book Co., Inc., New York City, 1934, p. 151.

gage brass strips, $1/2'' \times 1\,1/2''$, are bolted to the horizontal strips, one on either side, and bent outward to form the contact supports (Figure 2, *B*). The contact strips are cut from 30-gage brass plate and have the form and dimensions shown in Figures 2 and 3, *C*. A

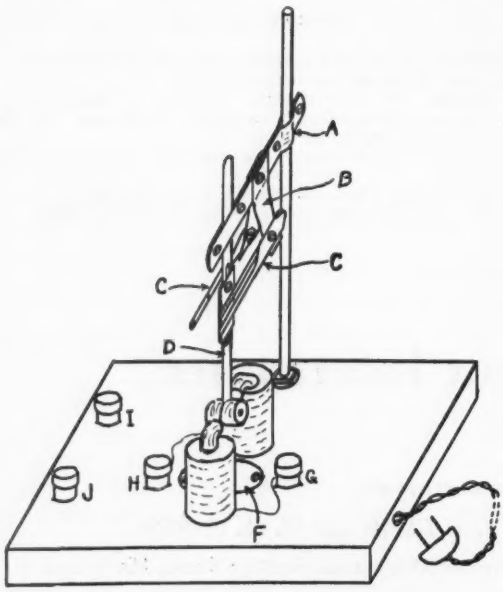

FIGURE 2

strip of platinum foil is soldered to the contact faces of these strips. The tapered ends serve as lugs to which the lead wires are soldered. They are insulated from the support strips with fiber washers. These parts are all assembled with 1/8-inch stove bolts.

The pendulum is cut from 30-gage brass plate and has the form and dimensions shown in Figures 2 and 3, *D*. A certain amount of cut and try trimming of the pendulum strip is necessary in order to get the proper tension. A different mass on the end would require a slightly different width. The pendulum bob can be any iron weight, such as two nuts held one on each side with a screw running through both. The mass of the bob we are using is about 15 grams. The slot in the pendulum is for the purpose of making possible adjustment in the position of the platinum foil in case one wishes to adjust the oscillation frequency by changing the length of the pendulum. The platinum foil is held in place with a bolt through the slot.

The core of the pendulum magnet is made from 3/8-inch soft iron rod as shown in Figure 3, *E*. Wire is wound separately on two spool forms. The spools are slipped in place over the two pole pieces and these are then connected by screwing the soft-iron cross-yoke in place. Each spool has 2500 turns of No. 30 enameled copper wire. The spools are connected in series. No claim is made for scientific design of this magnet. However, it is neat in appearance, has ample power for its purpose, and has sufficiently high impedance to operate satisfactorily directly from a 110-volt A.C. line. It does not overheat and draws about 0.35 ampere on 110 volts. The magnet is fastened to the center of the base by countersinking the cross-yoke in a depression chiseled in the base. A strip of brass plate laid across the cross-yoke and screwed into the base at each end holds the magnet firmly in place (Figure 2, *F*).

The leads from the magnet are connected to the binding posts *G* and *H* (Figure 2). Binding posts *I* and *J* (Figure 2) are for the leads to the stirrer magnet. The wiring, as far as possible, is concealed under the base, which is mounted on rubber feet at each corner.

The stirrer magnet core is of the dimensions shown in Figure 4. It is the field magnet from a 1936 model "Polar Cub" electric fan, which was found to be ideal for our purpose. It is wound with approximately 1000 turns of No. 30 enameled copper wire. It draws about 0.9 ampere on 110 volts.

The reaction vessel we use is a $1'' \times 8''$ test tube, which is supported by the magnet. A piece of rubber tubing 1/4 inch long is slipped against the lip to raise the lip slightly from contact with the magnet and to bring the test tube stopper (not shown) high enough so the impact of the iron ring does not knock it loose. (See Figure 4.) A 1/4-inch copper rod, 8 inches long, is bolted to the magnet and clamped in a stand to support the magnet and test tube over the constant-temperature bath.

The iron ring which actuates the stirrer is 1/2" long and 3/4" in diameter. It is cut from 20-gage sheet iron and lacquered to prevent rusting. Copper wire, passed through small holes drilled at opposite sides of one end

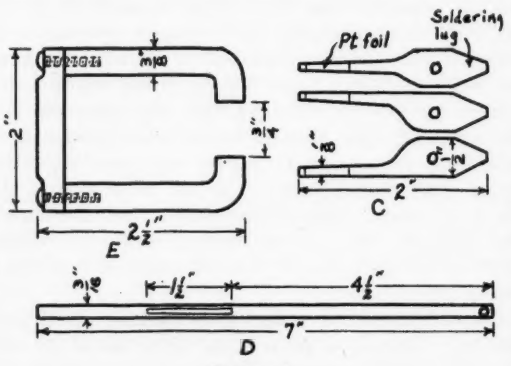

FIGURE 3

of the ring and twisted together in the center, is fastened to the glass stirrer with De Khotinsky cement. The stirrer-to-ring connection should be rigid.

The stirrer is a 5 1/2-inch length of 2-mm. cane glass terminated at the lower end by a flat spiral of about two turns. Several different kinds of wire were tried as stirrers but all were found to have considerable catalytic activity. In operation the test tube is fitted with a rubber stopper through which passes a tube to a gas buret.

Once the contacts are properly adjusted, the pendulum interrupter operates smoothly and continuously without attention other than starting at the beginning of a run. Before its construction other types of interrupters, such as a metronome or motor-driven commutator were considered, but it is felt that the pendulum interrupter has advantages over both of these, particularly from the standpoint of economy. The cost of the complete apparatus, excluding labor, was about three dollars.

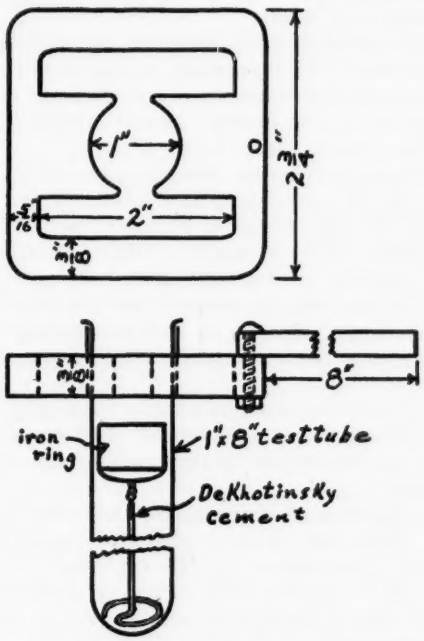

FIGURE 4

The experiment has been performed by classes using the above-described stirrer and also using hand shaking. Gas evolution is more uniform and results more reproducible using automatic stirring. The reproducibility of results obtainable is illustrated in Figure 5. Curves I and II are plots of $V_f - V_t$ against time and log $(V_f - V_t)$ against time, respectively, for the decomposition of 5 ml. of three per cent hydrogen peroxide (containing acetanilide inhibitor) catalyzed by 5 ml. of

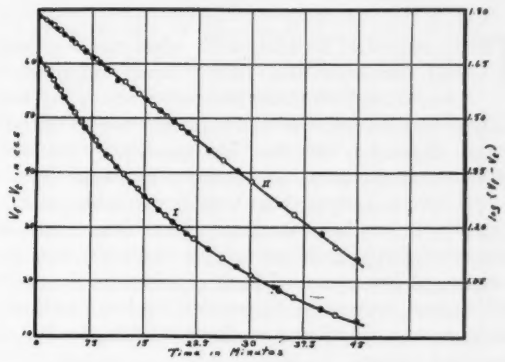

FIGURE 5

approximately 0.05 N potassium iodide solution. Circles and solid circles indicate the results for duplicate runs. V_f is the volume of oxygen obtained on heating the reaction mixture to complete decomposition and V_t the volume evolved at time t. The volumes were measured at the same temperature and pressure for each run. It is seen that smooth curves are obtained and that both runs yield the same value for the velocity constant, within the limits of the experimental error. The velocity constant, calculated from the slope of the first half of the log curve, is 0.368, with time in minutes.

An objection which might be raised against this type of stirring is that the heating effect of the stirrer magnet on the gas in the test tube will produce error in the measured volume of gas evolved. This error has been investigated and it is found to be negligible. Apparently the action of the iron ring stirs the air in the test tube sufficiently to keep it at the thermostat temperature.

The National Chemical Exposition

THE Chicago Section of the American Chemical Society is sponsoring the first annual National Chemical Exposition, to be held at the Hotel Stevens, in Chicago, December 11–15. It is reported that the original space allotments have been altogether inadequate for the large number of firms planning to exhibit. In addition to the exhibits of chemical products, plant and laboratory equipment, there will be several technical conference sessions at which new discoveries and developments will be discussed by foremost authorities. Among the subsidiary attractions will be the Annual Chemists' Salon of Photography. Photographs entered for this display should be sent to the Salon Committee, Chicago Chemists Club, Hotel Stevens, Chicago.

The JOURNAL OF CHEMICAL EDUCATION will be represented in one of the booths and all readers and friends of the JOURNAL are invited to make this their headquarters.

Capillary Tube Experiments with Gases

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THE School of Building in London has in all some 1500 students and their varied requirements form difficult problems for the science department. In chemistry the provision of a general course of fundamental character followed by specialized courses is found to be the most satisfactory method. For the general course, only a short time is available, and consequently it has been necessary to develop rapid and extremely simple technics to give students clear ideas of chemical principles. Many of these, of course, are well known, but some appear to be less familiar, in particular the use of long capillary tubes in dealing with gases and vapors.

This is a most effective method of demonstration which has also the advantage of giving accurate results without the necessity of elaborate precautions or corrections which might tend to obscure the principle involved.

As will be seen in the two examples described, the apparatus required does not involve any more than average laboratory skill in its construction or use.

DISSOCIATION

The phenomena of dissociation, although very important, are only rarely demonstrated since expensive time-consuming apparatus is usually thought necessary. However, the more significant facts may be shown using the apparatus illustrated in Figure 1.

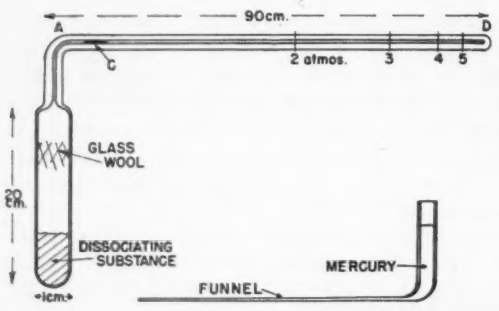

FIGURE 1

First, a 20-cm. length of one-cm. bore tubing sealed at one end, or a hard glass test tube of similar dimensions, is about one-quarter filled with some dry dissociating substance, such as $CaCl_2 \cdot 4NH_3$ or $ZnCl_2 \cdot 4NH_3$. A loose-fitting glass wool stopper is inserted near the open end and then a meter capillary tube with 2-mm. bore is bent and fused on. The glass wool, although not essential, is useful since it hinders the loss of ammonia. During sealing the wider tube should be kept as cool as possible. Next a one-cm. thread of mercury is introduced at *C*, using a length of fine-drawn soft tubing as a funnel.

After withdrawal of the funnel, the end *D* of the capillary is sealed. The apparatus is supported in an almost horizontal position, *A* being at the lower end, and the position of the mercury thread marked—a band cut from a piece of rubber tubing is useful.

The space between the mark and the sealed end of the capillary is divided into the fractions $1/2$, $1/3$, $1/4$, $1/5$, etc., and a mark placed at each. These will record the position of the mercury when the dissociation pressure is 2, 3, 4, 5, . . . atmospheres.

Finally, the tube containing the dissociating substance is supported in an oil bath for heating and the capillary tube passed through a hole in an asbestos shield.

The apparatus is now ready for use in showing:

(1) The increase of pressure with temperature, and the determination of the relation between these quantities.

(2) The reversal of dissociation on cooling.

(3) With two or more pieces of apparatus, the variation of pressures using different substances.

(4) With two or more pieces of apparatus, the independence of dissociation pressure of the amount of substance used.

The compound of calcium chloride with ammonia was first prepared by Berzelius and its dissociation was discovered by Faraday.

It is easily prepared by placing a few grams of fused calcium chloride in a 350-cc. conical flask, cooled in a water bath, and passing in dry ammonia with the usual precautions. As the gas is absorbed, the calcium chloride swells, cracks, and falls to powder. When absorption is completed, the product has approximately the composition represented by the formula $CaCl_2 \cdot 4NH_3$. The relation between dissociation pressure and temperature for this substance was expressed by C. Antoine[1] by the formula

$$\log p = 2.1361 + 0.023t$$

The substance $ZnCl_2 \cdot 4NH_3$ is similarly prepared from anhydrous zinc chloride and for this C. Antoine gave

$$\log p = 4.9445 \left(2.4391 - \frac{1000}{t + 449}\right)$$

[1] *Compt. rend.*, **107**, 836 (1888).

THE DETERMINATION OF VAPOR DENSITY

The method described does not give an absolute measure. Actually, two substances are used and their vapor densities compared, then if the value for one is known, that of the other can be calculated.

The specific gravities of the two liquids at ordinary laboratory temperature must be known.

A meter capillary tube as before described is carefully cleaned and dried and then prepared according to the following directions:

(1) Seal one end.

(2) Using the funnel, insert a thread of mercury (one cm. long, approximately) about halfway along the tube.

(3) Support the tube vertically, closed end at the bottom, and on the thread of mercury insert a thread (0.5 to 1 cm.) of liquid of known vapor density.

(4) Taking care to keep the tube cool, seal the top.

(5) When the sealing has cooled, open the end sealed at first, support the tube vertically, closed end down, and introduce a thread (0.5 to 1 cm.) of the liquid of unknown vapor density.

(6) Seal the top of the tube.

The apparatus is now ready for use.

Diagrammatically, the preparation of the tube may be represented as in Figure 2.

When the tube has cooled to atmospheric temperature, the lengths of the liquid threads are measured to 0.01 cm.

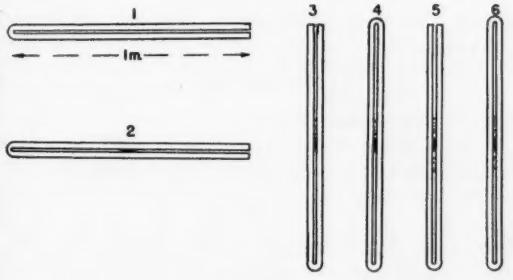

FIGURE 2

The tube, resting in a few glass rings, is then placed horizontally in a wider tube and heated by vapor passing along the wider tube (Figure 3).

Any convenient liquid may be used to provide the heating vapor—all that is necessary is that both liquids should be completely vaporized. The temperature need not be found. Obviously, the comparatively high pressure arising in the tube will mean that a temperature considerably above the boiling point of either liquid is necessary.

When both have vaporized, the lengths of the vapor columns on either side of the mercury thread are measured to 0.1 cm.

FIGURE 3

CALCULATION OF RESULTS

Let A ccs. be the volume occupied by one gram mol of vapor in the conditions existing in the heated tube; d cms. be the diameter of the capillary bore, L and l cms. be the lengths of the threads of liquid, of known and unknown vapor density, respectively, as measured before heating; V and v cms. be the lengths of the respective vapor columns as measured during heating; $S.G.$ and $s.g.$ be the respective specific gravities of the liquids, and $V.D.$ and $v.d.$ be the respective vapor densities.

Then the volume of the vapor of the liquid of known vapor density will be given by

$$\text{Volume} = \frac{\pi d^2}{4} \times V = \frac{\frac{\pi d^2}{4} L \times S.G.}{V.D.} \times A$$

whence

$$A = \frac{V \times V.D.}{L \times S.G.}$$

Since the temperature and pressure conditions of the two vapors are alike, for the liquid of unknown vapor density we have

$$A = \frac{v \times v.d.}{l \times s.g.}$$

Hence

$$\frac{V \times V.D.}{L \times S.G.} = \frac{v \times v.d.}{l \times s.g.}$$

In this equation, all the quantities are known with the exception of the unknown vapor density, which can therefore be easily determined.

This calculation is an approximate one, but when a more exact formula is applied it is found that the results agree within one per cent with those obtained using the formula given. This exceedingly simple method gives results quite as good as those obtained by elaborate technics and with great saving of time.

The liquids used as known or unknown can be any of the simple stable organic compounds—hydrocarbons, alcohols, esters, halogen derivatives, etc. The following have been selected as typical satisfactory compounds:

	S.G. at 20° (*Landolt-Bornstein*)
Benzene	0.8787
Methyl alcohol	0.7915
Ethyl alcohol	0.7894
Ethyl acetate	0.9005
Ethyl iodide	1.934
Chloroform	1.4827

Calibration of Volumetric Apparatus

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THIS paper describes a convenient method for calculating volumes of flasks, burets, pipets, pycnometers, etc., from the usual calibration data obtained with water as a reference standard. The method is sufficiently precise so that it can be used for calibrations of high accuracy; yet with suitable approximations it is readily adapted to all ordinary volumetric calibrations. The method has also been used with satisfactory results in presenting the theory of volumetric calibrations to students in elementary quantitative analysis. For this latter purpose it offers perhaps a somewhat more direct and logical means of making the necessary corrections and changes in units than the usual method, where calculations are based on tables in which the separate corrections and changes in units are combined, and where, therefore, the purpose and effect of each are concealed.

In the present method, the calculations are made in three steps: (1) the mass of water used in the calibration is calculated from the apparent weight by the application of a vacuum correction, (2) the volume at the temperature of filling the apparatus is calculated by multiplying the mass of the water by the absolute volume of one gram of water at this temperature, and (3) the volume of the apparatus at the desired temperature is then calculated from the volume at the temperature of filling.

For a calibration in which high accuracy is required, the mass of the water is calculated from its apparent weight by the formula:

$$M = W(1 + C) \qquad (1)$$

where M and W are in grams, and C is the vacuum correction in grams per apparent gram, obtained from the following table, which was calculated with the relation

$$M = W[1 + D(V_m - V_w)]$$

rather than with the usual less precise approximation. It is assumed that the full and empty apparatus will have been weighed in air of the same density, as a matter of convenience, to simplify subsequent calculations, and that the density of the brass weights is 8.4 grams per milliliter. While this second assumption is the least precise link in the present method of calculation, it introduces an uncertainty of only about two parts per million if Class S brass weights are used. This uncertainty may, of course, be further reduced by the use of Class M weights of known volume.

VACUUM CORRECTION PER APPARENT GRAM FOR WATER

Temp., °C.	*0.001220*	*0.001200*	*0.001180*	*0.001160*	*0.001140*	*0.001120*
			Air Density			
15	0.001077	0.001060	0.001042	0.001024	0.001007	0.000989
20	0.001078	0.001061	0.001043	0.001025	0.001008	0.000990
25	0.001080	0.001062	0.001044	0.001027	0.001009	0.000991
30	0.001081	0.001063	0.001045	0.001028	0.001010	0.000992
35	0.001083	0.001066	0.001048	0.001030	0.001012	0.000995

The temperature in the above table is that of the water during the *weighing*, and the air density, D, is calculated from the relation:

$$D = \frac{0.001293}{1 + 0.00367T} \cdot \frac{B - 0.00375HP}{760.0}$$

where D is given in grams per milliliter; T is the temperature of the air in the balance case, in degrees Centigrade, measured to the nearest tenth of a degree; B is the barometric pressure in millimeters of mercury, reduced to 0°C.; H is the relative humidity, determined with a good hygrometer or sling psychrometer;[1] and P is the vapor pressure of water at $T°$, in millimeters of mercury at 0°C., taken from the following table. Since D is a linear function of $B - 0.00375HP$ when T is constant, it is convenient to plot D against assumed values for this "corrected pressure," obtaining the parallel isotherms for 0.5° intervals; D may then be read quickly from the graph after a slide rule calculation of the corrected pressure.[2]

VAPOR PRESSURE OF WATER

Temp., °C.	*P, Mm. Hg*	*Temp.,* °C.	*P, Mm. Hg*	*Temp.,* °C.	*P, Mm. Hg*
15	12.8	22	19.8	29	30.0
16	13.6	23	21.1	30	31.8
17	14.5	24	22.4	31	33.7
18	15.5	25	23.8	32	35.7
19	16.5	26	25.2	33	37.7
20	17.5	27	26.7	34	39.9
21	18.7	28	28.3	35	42.2

It is evident that for all calibrations in which water is used as a reference standard at ordinary air densities the formula:

$$M = 1.00104W \qquad (1a)$$

is a good approximation.

V, the volume of the apparatus in milliliters, is calculated from the mass of water by the formula:

$$V = M \cdot 1/D \qquad (2)$$

where $1/D$, the reciprocal of the absolute density of water in milliliters per gram, is taken from the following table. The temperature is that of the water at the time of *filling* the apparatus, in degrees Centigrade.

VOLUME OF ONE GRAM OF WATER

Temp., °C.	*1/D*	*Temp., °C.*	*1/D*	*Temp., °C.*	*1/D*
15	1.000874	22	1.002206	29	1.004043
16	1.001031	23	1.002439	30	1.004343
17	1.001199	24	1.002682	31	1.004652
18	1.001379	25	1.002935	32	1.004970
19	1.001569	26	1.003197	33	1.005297
20	1.001771	27	1.003470	34	1.005632
21	1.001983	28	1.003752	35	1.005976

[1] MARVIN, "Psychrometric tables," Weather Bureau No. 235, 4th ed., Government Printing Office, Washington, 1915, 87 pp.

[2] WEATHERILL AND BRUNDAGE, "A revision of the atomic weight of silicon. The ratio $SiCl_4:SiO_2$," *J. Am. Chem. Soc.*, **54**, 3935 (Oct., 1932).

Once the volume at the temperature of calibration has been found, the volume at any desired temperature is calculated from:

$$V' = V[1 + K(T' - T)] \quad (3)$$

where V' is the volume at T'°C. and V the volume at T°C. For soda glass apparatus K has the value 0.000025; for pyrex, 0.0000096.

For most calibrations, calculations with the above formulas and tables can be greatly simplified by mathematical approximations in which addition is substituted for multiplication. For example, the volume of a flask holding an apparent weight of 996.18 grams of water at 25°C. is: 996.18 + 1.04 + 2.94 = 1000.16 ml. The value found by multiplication is 1000.15 ml.

Values used in making up the above tables were calculated or taken directly from data given in the International Critical Tables.

Better New Examinations from Old[1]

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RECENTLY fifty or more teachers of college chemistry have favored the authors of this paper with comments and criticisms on a plan of: (1) collecting from many institutions their best examination questions; (2) assembling them in a central depository; (3) determining their difficulty and differentiating ability; (4) classifying and duplicating them for ready availability for use by teachers in service.

These teachers are working in the smaller colleges. Their classes in general chemistry vary all the way from 15 members to 566, the median number being 85. The reason for seeking counsel from these teachers is that they are less likely to have facilities or time for the study and evaluation of their test questions than do workers in larger institutions. Further, groups of students fewer in number than 100 give less dependable indices of difficulty and differentiating ability than do groups of larger numbers when studies are made of their answers to tests.

Some uncertainties regarding the project as expressed in comments by these interested teachers warrant attention. In brief these "fears" may be labeled; their loyalty to essay questions, their belief that objectives of the local course may not agree with those of other institutions, that items in the collection may not cover all topics, that students might get access to the collection of questions, that such a procedure might lead to fixation of course content, and that it is too much like a "sermon barrel." Almost without exception, these comments indicate a failure of the proponents of the project to make themselves understood. There has been no statement that the questions to be studied have to be of any particular type.[2]

Further, previous statements have said that this project would make possible an adherence to the objectives of the local teacher that is not possible in standardized long-period examinations such as the annual releases from the Coöperative Test Service. The teacher, who is interested in the use of the service contemplated by this project, inspects its offerings of questions and chooses only those items for inclusion in his examination which are in harmony with his objectives. In the event that there are items which he deems desirable in the examination that he is constructing which are not yet in the collection, that teacher would, for a part of his test, use his own items to meet the requirements. If the procedure suggested above is followed in making up examinations, the authors see less likelihood of course content fixation than is now occurring because of the use of a given text or a given manual. In fact, the plan attracted the authors because it would enable teachers better to control the direction of their courses by this method of examination than by use of forms of examination now published.

True, there is a resemblance between a magazine of "guinea pig" questions and a "sermon barrel," but in the judgment of the authors the danger is mostly in the attitude of the teacher who uses the "barrel." The term "guinea pig" has come to symbolize a biological tool for use in experimentation. If our teachers may be induced to look upon their examination questions or questions from any other source as tools for use in experimentation, the objectionable connotation of "sermon barrel" will be lost.

There are two ways of considering the possibility of students securing copies of questions from the magazine in advance of the examination. The first is that the likelihood of that occurring for this project should be no greater than for other published test forms. Second, one of the authors has taken the position that if his students get and learn the answers to all of his 1000 or more test items those students probably have an ac-

[1] Presented before the Division of Chemical Education at the 99th meeting of the American Chemical Society, Cincinnati, Ohio, April 8, 1940.

[2] HENDRICKS AND HANDORF, "New examinations from old," J. CHEM. EDUC., **16**, 330 (1939).

ceptable mastery of his course. One wonders if this fear could not be allayed, at least partially, if the total examination spread were increased, *i. e.*, if a wider sampling of course content were always insisted upon. By so doing the teacher could minimize the effect of any single item upon the total score.

The use of the adjective "better" in the title of this paper is considered from two points of view: first, better in the sense of being more useful to the teacher; and second, better in the sense of being more dependable as tools of evaluation. In considering the first of these, it is not intended that a survey of test uses[3] be made, but rather to present some brief comments concerning the service of old examinations in improving the usefulness of new questions made from the old. In considering this service of old examination questions the authors are assuming that the major value of an examination is its contribution to student counseling.

There may be little that is new to the experienced teacher in the statement: "The most usable phrasing of an examination question often comes through a sort of evolution." To illustrate: This question was used by one of the authors in an examination last fall:

CASE I, 1. *Phrasing for its first use.*

Define each of the following by a formal definition: (1) An acid. (2) An indicator. (3) A salt. (4) A double decomposition reaction.

While scoring the answers from his students the reader was impressed by the fact that low scores on the answers were often due to a failure to know the elements of a *formal* definition. A check indicated this to be the case for over fifty per cent of the class of 137 students.

In an examination some weeks later he tried the following question upon the same class in which specific attention was called to the meaning of the term *formal definition:*

CASE I, 2. *A rephrasing for second use.*

Write *formal* definitions for each of these four terms: (1) Formula. (2) Mol. (3) Neutralization. (4) Allotropes. (A formal definition has three parts: the *name* of the term defined, its *classification*, and the *distinction* between it and others of its class.)

A later attempt to recognize the same weakness of the statement of the first question above was to state it:

CASE I, 3. *A third rephrasing.*

Give *formal* definitions of: (1) Definition. (2) A base. (3) Electrolysis. (4) An equation.

In this case calling for the *definition* of a definition prompts more pointed attention to what constitutes an adequate formal definition before the student starts definitions of any of the other terms. This discussion of the term, definition, should bring to mind many *other* terms[4] much used in essay type examination such as: contrast, illustrate, interpret, justify, etc. Their influence upon test results deserves attention similar to that given the word "definition" above.

Most teachers of chemistry consider the habit of recognizing use in the relation to the properties of a substance an important objective and will often include questions like the following:

CASE II, 1. *First phrasing.*

Briefly describe *three* uses of oxygen. Name the property involved in each case and show how that property makes the use possible.

In reading answers to this question, the problem of what constituted *acceptable* uses emerged. Oxygen is used chemically in any reaction in which oxygen is a reactant. Should the student who said, "Oxygen may be used to rust iron," be given as much credit for his answer as the one who told of its use in the acetylene torch?

The decision reached was that the next time this question is used it will be in the revised form:

CASE II, 2. *A rephrased statement.*

Briefly describe *three* uses of oxygen which are of economic importance. Name the property involved in each case, and show how that property makes the use possible. To be of economic importance, there should be a cash market for oxygen for such use.

It was found that reading answers to the questions stated as the last two was time-consuming, so an effort was made to modify the form in order to reduce the time for reading. The result for such a question for hydrogen is as follows:

CASE II, 3. *A more practical statement.*

In *five only* of the following blanks give the property of hydrogen or its use as the case may require. The use *must depend on* the property or the property *must determine* the use in each case.

Property	*Use*
(1) High heat of burning	(1) _____
(2) _____	(2) In balloons
(3) Combines with some oils	(3) _____
(4) Reacts with oxygen in oxides	(4) _____
(5) _____	(5) In preparing ammonia
(6) _____	(6) In preparing wood alcohol

When a comparison of the answers obtained in the two latter forms was made, there was no significant difference in validity or difficulty, the former took three hours to score, and the latter but two hours. The latter question-form merits favorable consideration from the standpoint of practicability.

Numerical problems[5] are a frequent item in college chemistry examinations. A study of answer papers for such items sometimes reveals reading practices which are hard to defend if the purpose of these questions is to help the teacher find student need for remedial instruction. To illustrate, the following problem may be used:

[3] HENDRICKS AND SMITH, "Service tests for chemistry," *Sch. Sci. Math.*, **35**, 488–91 (1935); HENDRICKS AND FRUTCHEY, "The uses of examinations," J. CHEM. EDUC., **15**, 237–40 (1938).

[4] HENDRICKS AND FRUTCHEY, "The essay examination in chemistry," J. CHEM. EDUC., **16**, 493 (1939).

[5] HENDRICKS AND HANDORF, "Examination practice in general college chemistry," J. CHEM. EDUC., **15**, 179 (1938).

CASE III, 1. *Usual type of chemical problem.*

Hydrogen has a density of 0.09 gram per liter at standard conditions. Phosphoric acid is 3.1 per cent hydrogen. Enough sodium (amalgam) was put into phosphoric acid to produce 25 liters (S.C.) of hydrogen. What weight of acid is needed?

An analysis of this problem reveals some six or eight elements of difficulty for the beginning student among which may be listed: the reaction involved, knowledge of chemical composition, and working concepts of density, per cent, decimals, division, multiplication, and subtraction. Such a question is often scored purely upon the basis of the correct numerical result, which is 72.6 grams. A zero grade may mean lack of understanding of any one or more of the above listed elements of difficulty. The score on such a question, to be useful to teacher and pupil, should attempt, at least, to localize the successes and difficulties of the student. After such a "post-mortem" over answers to the above problem, the following form was devised and tried out with satisfactory results.

CASE III, 2. *A diagnostic form.*

Hydrogen has a density of 0.09 gram per liter at standard conditions. Phosphoric acid is 3.1 per cent hydrogen. Enough sodium is put into phosphoric acid to produce 25 liters (S.C.) of hydrogen.

Read the following statements about this problem and by calculation, if necessary, decide their correctness. Mark the correct ones *C*, and mark the incorrect ones *X*. For those marked *X*, place a word, number, or phrase at the right which will, when substituted for the italicized phrase, make the statement correct. Note how it is done in the sample.

Statements	Place *X* or *C* here	Place correction here
Sample A. Hydrogen is *0.31%* of the acid	X	A. 3.1%
(1) The reaction is: sodium + phosphoric acid = *oxygen* + sodium phosphate.	——	(1) ——
(2) The weight of hydrogen needed is *3.1* × 0.09 g.	——	(2) ——
(3) *3.1%* of the acid = weight of hydrogen desired.	——	(3) ——
(4) Twenty-five liters of hydrogen (S.C.) weigh *2.15* g.	——	(4) ——
(5) The weight of acid needed is the weight of the hydrogen divided by *3.1*.	——	(5) ——
(6) The weight of acid needed is *72.6* g.	——	(6) ——

It has been shown that better new examination questions may be edited from the old ones if the teachers will be alert to the suggestions for revision which are to be found in the answers of students. This sort of use of old examination questions can be made by teachers of groups of any size.

The second use of "better" is in the sense of being better both as to validity and difficulty. As phrased by one writer:[6] "Does (the test item) discriminate between persons having much of the quality being measured and persons having only a relative small amount of the quality? And is the difficulty level of the test suited for the group for which it is intended?"

[6] FLANAGAN, "General considerations in the selection of test items and a short method of estimating the product-moment coefficient from data at the tails of the distribution," *J. Educ. Psychol.*, **30**, 675 (Dec., 1939).

To measure the degree of differentiation of an item, some basis for comparison must be used. Usually the scores of the papers on the examination as a whole are taken as a basis, on the assumption that those who make the high scores on the test are the successful students in chemistry, and vice versa. Therefore, if one determines the per cent of these best students who answer a given question correctly and the per cent of the poorest who likewise answer these same items correctly, two percentage values will be obtained which may and *should* vary widely, if the item has any validity or differentiating value.

To obtain the validity index in the quantitative manner, the procedure is briefy as follows: The examination papers are arranged in order of the total score and separated into quarters, or upper and lower fractions each of 27 per cent and a middle group of 46 per cent. Then the percentage of correct replies is determined on the item for each of the fractions of the group. By a statistical calculation this may be combined into a single figure referred to as the Biserial Correlation. The overall difficulty of the items may be obtained by getting the percentage of correct or incorrect responses of the whole group on the item.

A number of cases are given to illustrate the use of these percentage figures in determining the differentiating value of items. These have all been taken from examinations given by one of the authors.

CASE IV. *Good differentiation and sufficiently difficult.*

	Quarter	*Per cent*	
Complete and balance	Q_4 =	83	*Difficulty*
	Q_3 =	61	56
Se + H_2 heated ⟶	Q_2 =	56	
	Q_1 =	22	*Bis. r* 0.56

CASE V. *Excellent differentiation except in the middle half.*

	Quarter	*Per cent*	
1.18 g. of a metal reacts with	Q_4 =	90	*Difficulty*
acid to give up 0.02 g. of hy-	Q_3 =	45	47
drogen. What is the equivalent	Q_2 =	53	
weight? Assume atomic weight	Q_1 =	1	*Bis. r* 0.88
H as 1.			

CASE VI. *No differentiation, too easy.*

	Quarter	*Per cent*	
The general term for a process	Q_4 =	88	*Difficulty*
which changes the properties	Q_3 =	82	83
and structure of a substance is	Q_2 =	80	
(1) sublimation, (2) evapora-	Q_1 =	83	*Bis. r* 0.10
tion, (3) physical, (4) chemical,			
(5) sub-atomic.			

CASE VII. *Slight differentiation, too hard.*

	Quarter	*Per cent*	
According to the electron	Q_4 =	36	*Difficulty*
theory of valence NaH should	Q_3 =	24	23
exist.	Q_2 =	15	
	Q_1 =	16	*Bis. r* 0.24

The following question represents an attempt to test a student's application of the four controls: activities of metal, acids, oxidizing properties of the acids, and the solubilities of other products, in hydrogen generation:

CASE VIII. *Good differentiation and acceptably difficult.*

Preparation of hydrogen: Write a condensed statement for that pair of substances which will produce hydrogen *most successfully* from each of the following: (See notes below.)

(1) Potassium with either hydrochloric, nitric or (conc.) sulfuric acids.
(2) Magnesium with acetic, phosphoric, or nitric acids.
(3) Barium with steam or sulfuric acid.
(4) Potassium with (conc.) sulfuric acid or carbonic acid.

NOTES: *Activity series of metals:* potassium, barium, magnesium, zinc, lead, hydrogen, silver.
Activity series of acids: hydrochloric, nitric, sulfuric, phosphoric, acetic, carbonic.
Soluble: All compounds of sodium and potassium; hydroxides of sodium, potassium, barium; all nitrates, acetates, most chlorides.
Insoluble: Most other salts and hydroxides.

The results obtained from 125 students gave these values:

Quarter	*Per cent*	
Q_4 =	65	*Difficulty*
Q_3 =	45	45
Q_2 =	40	
Q_1 =	25	

Teachers of college chemistry often express the desire to learn whether their students have developed facility in the use of the scientific method. One aspect of that acquisition is a recognition of the relationship of observations to the inferences to which they lead. The next question illustrates an attempt to get evidence of ability in that direction.

CASE IX. *Acceptable differentiation, but too easy.*

Experiment. Below is a list of statements concerning the action of steam on hot iron or hydrogen on hot iron oxide. You are to classify them by placing: *D* before those which are directions, *O* before those which are *useful observations for this experiment*, *X* before those observations which are not useful in this experiment, *C* before those which are conclusions *related* to useful observations, and *A* before statements which are assumptions.

Statements

—(1) The iron filings were darker after the experiment than before.
—(2) There was steam mixed with the hydrogen produced.
—(3) Anhydrous copper sulfate turned blue when dry hydrogen passed over hot iron oxide and then over this sulfate.
—(4) Pass the hydrogen through calcium chloride.
—(5) Steam reacted with the hot iron.
—(6) There was less noise after a time but there was always some noise in the pneumatic trough.
—(7) Hydrogen formed water by reacting with oxygen in the iron oxide.
—(8) There was no air in the steam.
—(9) The cork in the gas pipe turned black.
—(10) Some of the steam mixed with the collected hydrogen had been formed by a chemical change.

An analysis of the answers 120 students gave shows:

Quarter	*Per cent*	
Q_4 =	90	*Difficulty*
Q_3 =	80	80
Q_2 =	70	
Q_1 =	60	

Of these nine questions only those should be reused which show the proper distribution between the four quarters or the upper and lower quarters and the middle group of the students. Or the question should be rewritten in the light of the students' answers in an effort to improve its differentiating value. Better examinations should include only those items which have, by use, shown high selectivity and an acceptable difficulty for the group to be measured.

If all questions considered were of the true–false type, the per cent correct or some function of that per cent could be used as an index of its difficulty. However, for those teachers who prefer to use questions whose answers may represent intermediate values between absolutely wrong and absolutely right, or questions of the essay type, it is suggested that the answers be scored on a scale of ten or twenty intervals which may then be handled in the manner customarily used in the determination of difficulty or the per cent of correct response in the various quarters.

A question which may have come to many readers is, "Do these indexes of difficulty and of differentiating capacity continue to be the same for a given question when it is used a second or third time?" Dr. Magnus Olson of the zoölogy department of the University of Minnesota, who is assembling a file of indexed zoölogy questions, states:[7] "The second use does not alter their validity (*i. e.*, differentiating capacity) nor does it have any appreciable effect upon the index of difficulty. This latter seems rather discouraging to me." In the Minnesota studies, Dr. Anderson[8] reports, "Items do retain their discriminative power to a marked degree."

Dr. Olson and Dr. Anderson both consider the results of analysis of answers to old questions of such importance that in the language of the latter, "It is well to type each examination question that receives analysis upon a card. The percentage values (for differentiation capacity) in the case of objective items and the mean scores in case of essay questions can be entered directly upon the card and the questions filed away for future use. It then becomes possible to select items or questions for examinations in terms of their discriminative value."

The authors of this paper would say with Dr. Olson, in summary, "that making examinations is not a task that one can complete and put aside." Old examination questions need to have their student answers studied either with a view to their assets for future use or, if they are not satisfactory, with a view to modification of their phrasing or form with the intent of further trial before discarding them completely or filing for future reuse. In other words, an examination question has to become *old*, *i. e.*, used at least once, before its better *new* can be produced and its worth demonstrated.

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[7] In a private communication to one of the authors.
[8] ANDERSON, "Evaluation of test items," *Studies in College Examinations*, University of Minnesota, 116–20 (1934).

A Simple Demonstration Stroboscope and Circuit for Charging Condensers to High D.C. Potentials

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THE stroboscope is an instrument used to observe the successive phases of a periodic motion by means of synchronized flashes of light. The motion must be periodic and of a high enough frequency (about 16 per second) to utilize the persistence of vision. The applications of a stroboscope and its various forms have been described.[1] The purpose of this article is to describe a stroboscope of simple design which was constructed from inexpensive and easily accessible materials.

Figures 1 and 2 show the complete apparatus with circuit. An automobile distributor mounted in such a

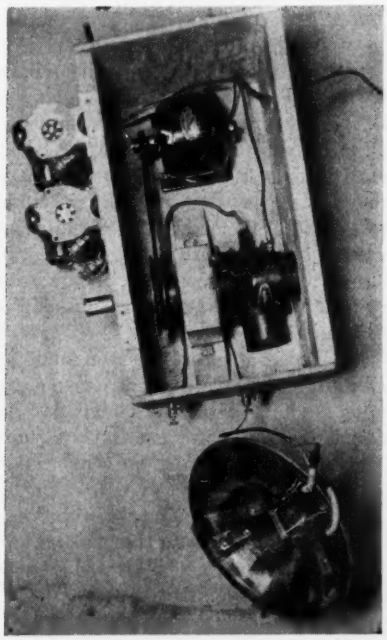

FIGURE 1.—STROBOSCOPE APPARATUS

way that its shaft could be rotated by means of a 1/50 H.P., 110-v. D.C. motor[2] served as an interrupter for the six-volt primary current of an automobile spark coil. (The spark coil and distributor were obtained from a salvage shop for about two dollars.) The frequency of the neon tube flashes, which depends on the speed of the motor, was measured by means of a revolution counter on the distributor shaft, since each revolution of the shaft corresponded to six flashes in the tube. A reflector from a discarded electric heater supported the neon tube. Any small gas discharge tube is suitable for use as a light source.

For frequency determinations or observations of

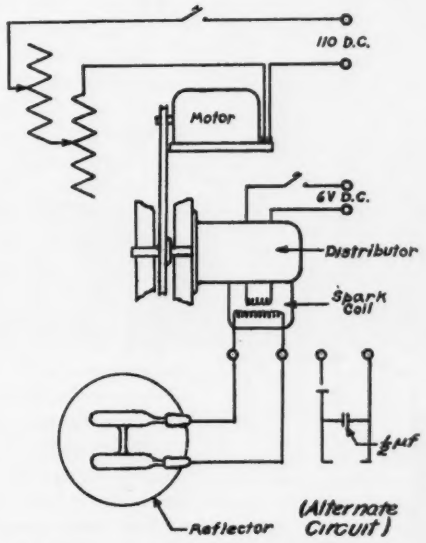

FIGURE 2.—DIAGRAM OF ELECTRICAL CONNECTIONS OF STROBOSCOPE

periodic motion, the frequency of the flashes was varied by means of a variable resistance in series with the motor. Stop watch observations of the dials of the revolution counter gave the necessary data for computing the frequency of the flashes since:

no. of flashes/sec. = (no. of rev./sec.) × (no. of flashes/rev.)

Any frequency of which the actual frequency is a multiple causes the objects to appear stationary. However, multiples of the actual frequency displace the objects closer together. Thus the absolute frequency can be determined.

The frequency limits of the stroboscope are determined by the speed of the motor and the size of the pulleys. With two variable resistances of 195 ohms each in series with the motor, a four-inch pulley on the

[1] EDGERTON AND GERMESHAUSEN, "The stroboscope and high-speed motion picture camera as research instruments," *Am. Inst. Chem. Eng.*, **30**, 420–37 (May, 1934); BAHLS AND KNOWLES, "The stroboglow," *Elec. J.*, **28**, 250–3 (April, 1931).

[2] Any variable speed motor with sufficient power could, of course, be used.

distributor shaft, and a one and one-half-inch pulley on the motor, the stroboscope used by the authors had frequency limits of 15 and 95 flashes per second.

An equally important use of the secondary circuit has been for the purpose of charging condensers, which were used in single-flash photography, to high direct-current voltages (4–8 kilovolts). This is accomplished by placing a point-plane spark gap in the secondary circuit in series with the condenser to be charged, as indicated in the alternate circuit of the figure.

An Efficient Fractional Distillation Column

An Experiment Suitable for Use in Beginning Organic Laboratory Work

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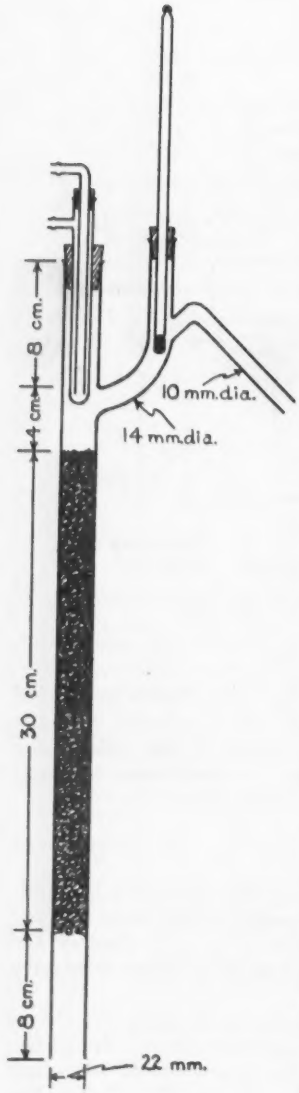


FIGURE 1

MANY of the laboratory manuals used in beginning organic chemistry contain an experiment on "fractional distillation." The distillation of coal tar or petroleum is frequently carried out and such experiments are useful because they parallel industrial processes, but these experiments lead to certain "cuts" or "fractions" which are mixtures of compounds and do not illustrate the isolation of the pure components. In other manuals, the distillation experiments described do not demonstrate the separation of compounds by true fractionation in a column. Instead, these experiments illustrate the process of multiple distillation. The fractionating devices used—Wurtz bulbs, Hempel tubes, and Vigreux columns—are very inefficient, the experiment is time-consuming and frequently requires more than one laboratory period for completion. The results are disappointing and unsatisfactory to the student. He gets the idea that isolation of pure compounds by fractional distillation is either impossible or is such a tedious process that the result is not worth the effort.

The technical developments in the chemical industries on fractional distillation have far outstripped the laboratory procedures customarily employed and are quite different from the experience which a student usually gets in his organic laboratory work. The chemical engineering students soon find out that there are efficient stills for the separation of compounds and naturally conclude that fractional distillations are possible on an industrial scale but not in the laboratory.

The recent work of Fenske[1] and his collaborators has emphasized the value of using packed columns and demonstrated their efficiency. The studies emphasize the importance of the nature of the packing, insulation of the column, and reflux control. There are excellent laboratory fractionating columns available from several companies,[2] but the cost renders their use by students prohibitive. Hence, an effort has been made to design a suitable column and provide an illustrative experiment for beginning students in organic chemistry.

In designing a column for use by large numbers of students it is desirable to have one which is (*a*) rugged enough to avoid excessive breakage, (*b*) efficient enough to give good separations in one distillation, (*c*) fast enough in rate of distillation so that the experiment can be completed in two hours, and (*d*) as inexpensive as is compatible with the foregoing requirements.

After several trials the column shown in Figure 1 was adopted[3]. It is frankly a compromise which has been found suitable for use in beginning laboratory classes, organic preparations of various types and, with certain modifications, finds considerable application in research. For the experiment described below and for many separations where a 15° to 20° difference in boiling points of the components exists, it has been found

[1] FENSKE AND CO-WORKERS, *Ind. Eng. Chem.*, **24**, 408 (1932); **26**, 1169, 1213 (1934); **28**, 644 (1936); WHITMORE AND LUX, *J. Am. Chem. Soc.*, **54**, 3448 (1932).

[2] American Instrument Co., Silver Spring, Maryland; Scientific Glass Apparatus Co., Bloomfield, New Jersey.

[3] This column without the side-arm test tube and carborundum may be obtained from Corning Glass Co., Corning, New York, at a cost of about $1.00.

that a packing of crystalline carborundum is satisfactory. The pieces should be about the size of grains of puffed rice. The following paragraphs represent the discussion and procedure given to the students in mimeographed form for their experiment.

EXPERIMENT NO.—

FRACTIONAL DISTILLATION

Discussion.—The basis of the separation of liquids by fractional distillation lies in the fact that when a liquid mixture (other than an azeotropic or constant-boiling mixture) is *partially* vaporized, the resulting vapor is richer in the more volatile component than was the original liquid. If this new vapor is then condensed and again partially vaporized, and the process repeated a sufficient number of times, the vapor will eventually be that of the pure lower-boiling component. This operation may be accomplished rapidly and without loss by means of a *fractionating column.*

The ordinary type of fractionating apparatus consists of a vertical tube mounted above the flask containing the mixture to be separated. The column is arranged so that most of the vapor which enters it is condensed and returned to the flask. It must also provide a large area of contact between the ascending vapor and the returning liquid. At the surface between these two phases part of the vapor condenses with the liberation of heat which causes partial vaporization of the liquid. The process is repeated continuously as the vapor traverses the tube. The material reaching the top of the column thus becomes highly concentrated with respect to the more volatile component.

From the foregoing description it is obvious that it is desirable to have a device for regulating the amount of liquid returning through the column. This may be accomplished by the use of a side-arm test tube as a "cold finger" condenser, shown in Figure 1. By raising or lowering it the amount of reflux may be controlled. The *reflux ratio* is the quotient of the amount of liquid returning through the column to the amount collected in the receiver during the same time interval.

The factors of greatest importance in connection with the efficiency of a column are as follows: (*a*) length, (*b*) reflux ratio, (*c*) packing material, and (*d*) temperature control.

Increasing either the length of a column or its reflux ratio will result in a sharper separation. In practice both these factors are limited by *flooding*, which is discussed below.

The packing material must provide a large surface area and yet leave sufficient free space to permit the counter-flow of liquid and vapor. Two packing materials of the same particle size and shape are not necessarily of identical efficiency. Apparently such factors as thermal conductivity and adsorption are also involved. Among the better packing materials for laboratory columns are crushed carborundum and glass helices.

For maximum efficiency, a column should be so completely insulated that no condensation occurs along the sides of the tube below the reflux control. Such complete insulation would, of course, be very difficult to attain. Fortunately, in the distillation of liquids boiling below about 110°, it is usually sufficient to wrap the column with several layers of asbestos paper. For higher-boiling liquids, or in the case of very long columns, it may be necessary to provide the column with an electrical heating jacket.

The presence in the column of an excessive amount of liquid results in *flooding;* the free space becomes filled with liquid, which may be forced up through the column by the pressure of the ascending vapor. Flooding may result from excessive length or poor insulation of the column. It may also be due to improper manipulation, particularly in connection with attempts to operate at very high reflux ratios or to distil too rapidly.

Procedure.—Assemble the fractionating column as shown in Figure 1 and then set it up as shown in Figure 2. Mix 100 cc. of carbon tetrachloride and 100 cc. of toluene in a one-liter round-bottomed flask and add a few chips of clay plate. Connect the flask to the fractionating column with a good cork. Mount the apparatus on a ring stand with the flask resting on a wire gauze. Make sure that the ring holding the gauze is far enough above the table top to accommodate the burner. Provide the column with a thermometer and a water-cooled condenser, both fitted with clean, tight corks. Use a dry 100-cc. graduated cylinder as a receiver. Arrange the reflux control in approximately the position shown in the diagram. Connect it to the condenser with rubber tubing and run a slow stream of water through both. Ask the instructor to inspect the apparatus.

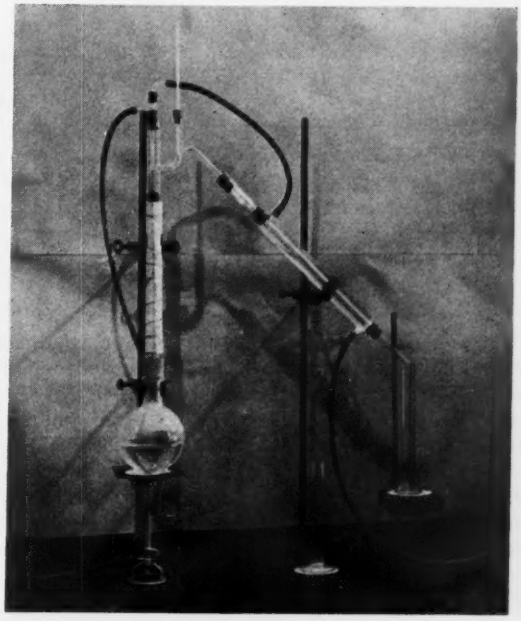


FIGURE 2

Heat the liquid to gentle boiling. While the column is warming, prepare a sheet of graph paper for recording the boiling point and volume of distillate at five-minute intervals throughout the distillation. After about five minutes the column will become hot and condensation on the cold finger will begin. Adjust the burner until about 1.5 cc. per minute is being collected in the receiver. The amount of liquid condensed on the cold finger should be such that the returning stream just fails to break into drops. Collect the carbon tetrachloride boiling between 75°–77° and record its volume. When about 90 cc. have been collected the temperature will rise above 77°, even though distillation is carried out very slowly and at a high reflux ratio. At this point transfer the carbon tetrachloride to the bottle provided for this purpose and collect separately the material boiling at 77°–108°. Note the tendency of the column to flood as the temperature reaches the latter figure. After the temperature has remained at 108° for about two minutes record the volume of the material collected between 77° and 108°. This portion is a mixture of the two components; if a quantitative separation were required it would be necessary to refractionate it. The residue in the flask now consists of pure toluene. If time permits, distil it through the column after making any necessary adjustment of the reflux control, and record its volume and boiling range. Extinguish the burner and allow the apparatus to cool for about ten minutes before dismantling it. Measure and record the volume of the residue in the flask. This represents the "hold-up" of the column and flask. Combine the residue with the toluene fraction and transfer it to the bottle provided on the side-shelf.

The plot of the boiling points versus volume of distillate made by the student results in a curve which is an

index of the performance of the column and the technic of the operator. A typical curve obtained with this carborundum-packed column is shown in Figure 3,

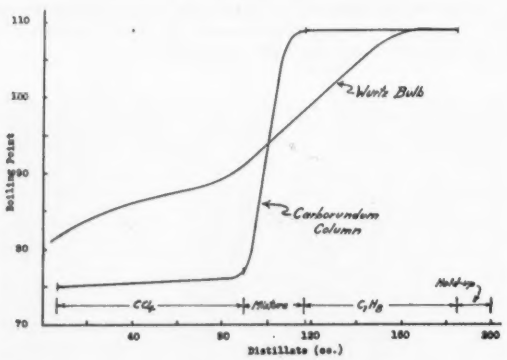


FIGURE 3

which also illustrates the results of a similar distillation with a Wurtz bulb. With the packed column, about 90 cc. of carbon tetrachloride (b. p. 75°–77°), and 71 cc. of toluene (b. p. 108°–109°) were obtained. The residue was 15 cc., which represents the "hold-up" of the apparatus. This residue is toluene, so the recovery of toluene was 86 cc. The intermediate mixture amounted to 23 cc. The only pure fraction obtained with the Wurtz bulb was about 31 cc. of toluene.

OTHER USES

The column shown in Figure 1 is rather large in diameter so that a fairly rapid rate of distillation may be used. The column can therefore be used in a considerable number of organic preparations where reasonably large amounts of material are to be distilled. The hold-up in this column is about 15 cc. In certain research work it is desirable to use a column of 11–12 mm. diameter, in which the hold-up will be about one-fourth as great.

For liquids which boil above 110° it is advantageous to heat the column by wrapping No. 22 Nichrome wire around a layer of asbestos paper, spacing the turns about 0.5 cm. apart, and covering the heating element with a layer of asbestos paper. The heat input is controlled by means of a slide-wire resistance. It is also desirable to wrap the side tube with asbestos rope.

The column may also be used for fractionation *in vacuo*. In this case all connections must be tight and a fraction cutter attached to the end of the condenser.

For the separation of liquids which boil very close together the glass helices recommended by Fenske[4] should be used. In this case the column must be heated in order to prevent flooding.

[4] FENSKE, ref. 1. Also PRICE AND MCDERMOTT, *Ind. Eng. Chem., Anal. Ed.*, **11**, 289 (1939). The helices may be purchased from the Scientific Glass Apparatus Co., Bloomfield, New Jersey, or American Instrument Co., Silver Spring, Maryland.

(From the Lyman C. Newell Collection)

OBVERSE AND REVERSE OF THE FABRE COMMEMORATIVE PLAQUETTE, STRUCK BY THE FRENCH MINT

HIGH-SCHOOL NOTES

Teaching Secondary-School Chemistry: A Study in Method

CHARLES HAYS CRAIG
Lawrenceville School, Lawrenceville, New Jersey

CHEMISTRY has long been regarded by secondary-school students as one of the most difficult subjects in their curriculum. A careful examination of the requirements in chemistry published by the College Entrance Examination Board does not reveal any subject matter hard for the average student to understand, provided he masters the fundamentals or underlying principles of the science when they are presented early in the course. As a matter of fact, by diligent application even the dullest students can master the material successfully.

Despite the nature of the subject matter involved, it happens all too frequently that a considerable group of students of average, or more than average ability, get off to a poor start and have difficulty with the course throughout the entire year. Most of them, by working hard prior to the examinations, learn enough to get a passing grade; but their gain from the course is small as compared with that of the relatively few who have understood and appreciated its significance during the school year.

If, as contended, the subject matter of secondary-school chemistry is not intrinsically difficult, how shall we explain the opinion, generally held, that this study of chemistry at its first level is an arduous and perplexing task? Experience leads me to think that it is rooted in methods of teaching rather than in any special difficulty in comprehending the subject matter involved.

In the first place it is usually the student's initial venture into the realm of science, with its necessary stress on definite expression and accuracy of interpretation. Closely allied to this is the fact that the new vocabulary, which a student must acquire before he can fully appreciate the underlying principles involved, often proves confusing. Moreover, if he fails to learn valences, he will soon be laboring under an impossible handicap, since he will be unable even to write equations—let alone balance them. The need of symbolizing facts in the form of equations and of thinking in such terms is hard for many to grasp at the outset. However, the main difficulty—at least after the first few weeks—centers in the great mass of facts and principles to be assimilated.

This difficulty, arising out of the amount of factual knowledge that must be acquired, is greatly enhanced by the readiness with which the average student forgets. A week may have been spent on the general subject of ionization, during which time such topics as electrolysis, hydrolysis, and repression of ionization apparently have been mastered thoroughly by most of the class. At least, the grades attained in a full-period test would seem to indicate that such was the case; however, by the time the review period arrives, or even when a new topic is taken up that requires as its background an understanding of the application of the theory of ionization, it appears that the majority of the class have forgotten almost completely what they had apparently learned with regard to that subject.

In an attempt to help my students meet this basic difficulty, I have for a number of years used what might be called a "notebook-outline" method of presenting the factual material in my chemistry classes. As I have found it extremely helpful in teaching boys secondary-school chemistry and believe it a pedagogically sound method, I am presenting it in the hope that it will prove useful to others.

Each member of my class is asked to procure a notebook (not loose-leaf) about 10″ × 8″, containing approximately fifty pages. At the first meeting of the class each boy is given a sheet, on which is mimeographed a table of contents for his notebook, and he is told to paste or copy it in the front of his notebook. The table of contents follows:

TABLE OF CONTENTS

Chapter		*Page*
I	Definitions	1
II	Lab Preparations, Properties, and Uses	6
III	Types of Equations	12
IV	Theory	13
V	Problems	18
VI	Ionization	23
VII	Commercial Preparations and Metallurgy	27
VIII	Miscellaneous Experiments	31
IX	Common Names, Formulas, and Uses	34
X	Organic Chemistry	36
XI	Identification Tests (Anions and Cations)	39
XII	Miscellaneous	43

It will be observed that provisionally I divide the subject matter of the course into twelve parts. A different division of the material may commend itself to other teachers. The main idea is to have the student, as a part of his daily task, summarize the subject matter of the lesson under the proper head.

Let me indicate how this method works in practice. During the first week or two, I am very careful to take the time to dictate, or write on the board, the material I advise putting in the notebooks. During the year we prepare oxygen, hydrogen, hydrogen chloride, chlorine, bromine, iodine, carbon dioxide, sulfur dioxide, hydrogen sulfide, nitrogen, and nitrous oxide in the laboratory and study them in detail in the classroom. Chapter II (for this and the references to the chapters which fol-

low consult the Table of Contents above) in the notebooks provides space for a summary of what we learn of these substances. Oxygen is considered first in our texts, and early in the course I indicate quite fully on the board my suggestions for a summary of their knowledge of oxygen in the notebooks. This includes a sketch of the apparatus, the equation for its preparation, its physical and chemical properties (with suitable equations to illustrate the chemical properties), its uses, and the reason for its collection by the downward displacement of water. This material can be easily expressed in outline form in a half-page of their notebooks. Naturally I do not insist that the students necessarily follow my form of expression, but I seek to encourage initiative on their part in outlining the material. When we take up hydrogen and the other substances that are included in this section, I do not put the material on the board in detail as in the case of oxygen. After calling attention to its distinctive characteristics, I content myself with placing on the board some such notation as "Chapter II—(2) hydrogen," and maybe ten days later, "Chapter II—(3) carbon dioxide." That signifies that as part of their preparation the students are to summarize in Chapter II the preparation, properties, etc., of hydrogen and carbon dioxide, respectively.

By early December the boys have obtained a good idea of what chemistry is all about. Let me indicate how this system is operating at this stage of the course. The lesson for the week deals with "Sulfur, Its Oxides and Acids." It contains three terms that are new to the class and which should be included in their list of definitions. So I write on the section of the board where they have become accustomed to look for definitions: "Chapter I—amorphous, allotropic, dehydrating agent." By this time they are aware that they are expected to write the definitions of those terms in Chapter I of their notebooks.

In this chapter of their text sulfuric acid has been referred to for the first time as "oil of vitriol"; and "white vitriol" and "saltpeter" have been briefly discussed. Thus, under Chapter IX, I have the boys indicate the formulas and uses of these substances. At one time I satisfied myself with simply giving, or calling the students' attention to, during the review period, a list of fifty or so "common names" in the back of their text, and telling them that they would be responsible for them in the approaching examination. Now members of the class are encouraged to add these names to their vocabulary as they appear throughout the course. If I can speak of "limewater," "aqua fortis," "vinegar," or "caustic soda," and be reasonably certain that they know what I am talking about, it not only simplifies their review, but is of large value to them throughout the school year.

In this lesson the "contact method" for the commercial preparation of sulfuric acid has been explained. Hence, under Chapter VII, they are asked to outline this important process by putting down the equations involved, indicating the catalysts and conditions, and sketching the apparatus used. Other commercial processes that we include each year in our notebooks are the Frasch, Castner, Vorce, Arc, Cyanamide, Ostwald, Solvay, Hall process for aluminum, and the blast furnace for iron.

In this same lesson the preparation of sulfur dioxide is discussed. Hence I write on the board: "Chapter II—(7) sulfur dioxide." Under this head the student learns that usually concentrated sulfuric acid acts on metals to liberate sulfur dioxide. Hence under Chapter III, I dictate: "a metal plus concentrated sulfuric acid yields the sulfate of that metal plus sulfur dioxide plus water." I have found such general rules for writing equations so helpful in aiding the student to gain confidence and ability in writing equations that it may not be out of place to mention a few more:

(1) Any acid + any base yields a salt + H_2O
(2) K, Na, Ca, Sr, and Ba + H_2O yields the base + H_2
(3) Metals more active than hydrogen + HCl or dilute H_2SO_4 yield the salt + H_2
(4) A carbonate + an acid yields the salt + CO_2 + H_2O
(5) An acid anhydride + a base yields the salt + H_2O
(6) Any hydrocarbon completely burned yields CO_2 + H_2O

Under Chapter XI, I point out the test for the sulfate and sulfite ions, telling the boys to indicate these tests with suitable equations in their notebooks. Here again I used merely to tell them late in the spring that they should be held responsible for all the cations and anions they had identified in the laboratory. But now, since each test is given to them as encountered in the text, they are familiar with them even before they have to use them in the laboratory.

Because the material in these notebooks is in outline form, it should not be supposed that they contain merely the least possible amount of information necessary to enable the boys to pass a college board examination. These notebooks contain practically everything taught throughout the course, including considerable material supplementing the textbook.

I will make only brief reference to some of the other divisions. One of the most important is Theory (Chapter IV), which is divided into four parts: Molecular, Atomic, Ionic, and Electronic. First *facts* are listed, then the *laws* that summarize those facts, and lastly the assumptions underlying the *theories* that explain these facts and laws. For example:

CHAPTER IV.—Theory p. 15

II. Dalton's Atomic Theory.
  (*a*) It is a *fact* that mercuric oxide always contains 92.6 per cent mercury and 7.4 per cent oxygen.
  (*b*) This and similar facts are summarized by the Law of Definite Proportions (p. 45—the page on which that law is stated in their texts).
  (*c*) Those *facts* and that *law* are most adequately explained by Dalton's Atomic Theory whose main assumptions are: (p. 48).

Under Chapter V (Problems), I have found it practical to put on the board for copying a simple problem, and its solution, of each of the basic types—a percentage composition, a true formula, a weight to weight, a

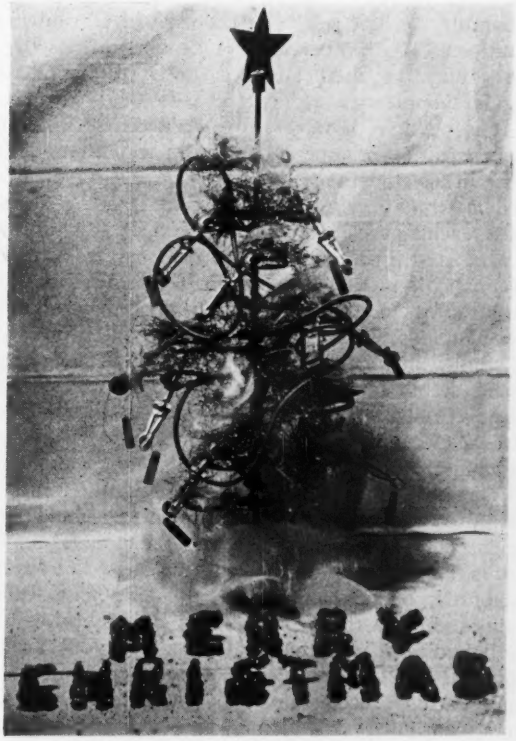
weight to volume, a volume to weight, a volume to volume, a change in volume to S.T.P., and a molarity–normality type. As soon as the students realize that practically all problems may be reduced to one of these types, or at least a combination of them, they lose much of their fear of numerical chemistry.

The method of teaching commended in this paper is based on the assumption—well grounded, I believe—that much of the difficulty students experience in secondary-school chemistry is due to the trouble they have in keeping in mind the large quantity of material constantly given them. These notebooks serve admirably to keep this knowledge refreshed and complete. After a month or so, I frequently assign as an additional part of the lesson one section of the notebook to review. This often can be made more helpful by assigning those parts that will be of direct aid as background for that day's lesson. For example, if we are taking up the Vorce cell for the preparation of chlorine and sodium hydroxide, it will prove helpful to assign a review of Ionization (Chapter VI). However, it is at examination time that these notebooks become of the greatest value. It is difficult for the average boy with his textbook in hand to review satisfactorily the entire course by himself. It is, however, a relatively simple matter for him to review his notebook section by section. There, in his own handwriting, in a manner familiar to himself, he has summarized, classified, and therefore simplified the entire course. I have found that students in other classes who do not use a notebook system frequently study the notebooks of my class. How much more benefit they would have derived if they had prepared them themselves!

Occasionally one of my colleagues has raised the question whether I am not making the course too easy for the students, and whether it would not be better for the student to do his own classifying. I am not one, however, who believes that a teacher should merely give his students an opportunity to learn. I definitely feel I am being paid to teach. Furthermore I feel that at its first level education consists in mastering the necessary facts. This entails hard work on the part of the student and drill on the part of the teacher. After one has mastered the facts, he can be expected to think with them. It is impossible to think with an empty mind, and while the ideal educational plan does not consist merely in memorizing a mass of factual knowledge, thinking is absolutely impossible without that mass of details. The student who accepts what we say without criticism and without thinking for himself is no doubt very unsatisfactory, but even more unsatisfactory is the student who attempts to explain something about which he knows nothing. Consequently I feel that this method of presenting the factual material in elementary chemistry is sound from a pedagogical point of view.

Merry Christmas To All!

Chemistry classes can get into the spirit of this holiday season with the project of a chemical Christmas tree, such as the one shown here. Students at South Haven High School, South Haven, Michigan, made this tree from ring stands, rings, buret clamps, and rubber tubing; they decorated it with copper foil and sheeting, glass wool, and colored solutions, under the direction of Wilamena Schnooberger, teacher of chemistry. The gay, glistening "Merry Christmas" consists of $K_2Cr_2O_7$ letters, shining in right merry good cheer. The student photographers who took pictures of the project were Robert Tait and Gwynn Thayer.



LETTERS

A Lecture Demonstration Course in Organic Chemistry

To the Editor:

A number of inquiries relative to the lecture demonstration work in organic chemistry, that is being offered in the chemistry department at Purdue University, has prompted this note.

At the outset, the writer wishes to state that the lecture demonstration course, which is being offered, is given in response to a specific need and not as a substitute for regular laboratory work. After seven years' experience in the use of lecture demonstrations in organic chemistry, the writer is still of the opinion that lecture demonstrations cannot be used as the one and only means of teaching laboratory technic.

The writer firmly believes that a four-fold set of objectives should justify the presentation of *any* laboratory course. The laboratory instructor should aim to teach his students *to do correctly, to sense accurately, to think clearly*, and *to record results intelligibly*. If these be the objectives underlying laboratory instruction, which most instructors will readily concede, then it is quite obvious that lecture demonstrations cannot serve as a substitute for regular laboratory work. We still live in a world in which we learn to do by doing, experimentation being the teacher par excellence. One cannot, therefore, expect to teach a group of students the art of laboratory technic solely by the use of lecture demonstrations. The proper type of demonstrations, to be sure, may be used advantageously to supplement regular laboratory work.

It is possible, however, to give a course in lecture demonstration organic chemistry in which one desires to train his students *to sense accurately, to think clearly*, and *to record results intelligibly*, but is not concerned with teaching the art of doing correctly. It is just such a need that a course in lecture demonstration organic chemistry is intended to fill; for these objectives may be attained, in the opinion of the writer, without the use of regular laboratory work. The following series of studies, in which one hour is devoted to each assignment, seems to meet these particular needs in organic chemistry: (1) Notebooks, J. CHEM. EDUC., **10,** 401–12 (1933), (2) saturated hydrocarbons, (3) unsaturated hydrocarbons, acetylene, (4) halogen compounds, (5) alcohols, (6) ethers, (7) aldehydes, (8) ketones, (9) saturated monoacids, (10) lactic, tartaric, and citric acids, (11) acid anhydrides, (12) acyl halides, (13) esters, (14) soaps and salts, (15) melting-point studies, calibration of a thermometer, (16) boiling-point studies, calibration of a thermometer, (17) carbohydrates, (18) carbohydrates, continued, (19) amides, (20) amides, continued, (21) amines, (22) amines, continued, (23) amino acids, proteins, urea, (24) amino acids, proteins, urea, continued, (25) nitriles, (26) aromatic hydrocarbons, (27) aryl halides, (28) nitration, (29) reduction, (30) sulfonation, (31) diazotization, (32) qualitative organic analysis.

The needs of a rather large group of students in organic chemistry are served adequately by a lecture demonstration course of this type. In this group may be included all beginning students in organic chemistry who never expect to make any practical use of their laboratory training, but who will always find themselves confronted with problems in everyday life that compel them *to sense accurately, to think clearly*, and *to record intelligibly*, mentally or otherwise, if they would be successful in their chosen profession.

A few details relative to the administration of the course should be given. In order that the students may be able to see the results of the experiments, and in order to facilitate oral quizzing, the sections are limited to from twenty to thirty students. The demonstrations are correlated, as far as possible, with the regular lectures. Test-tube reactions are stressed. Simple preparations and the most important type reactions of the various homologous series are considered. Students are expected to spend two hours of outside preparation previous to each lecture demonstration exercise, reports on this outside work being required. The students are required, furthermore, to submit their notes, for correction and grading, at the close of the lecture demonstration hour. It would seem, therefore, that lecture demonstrations of this type may serve as adequate teaching tools.

E. F. DEGERING

PURDUE UNIVERSITY
LAFAYETTE, INDIANA

Mu and the Micron

To the Editor:

This note is to call attention to the fact that, when used in measurements, the Greek letter, mu (μ), should indicate one millionth just as the Latin, milli-, indicates one thousandth. Some time ago I copied the following table, dated 1893, from Erdmann. It is in keeping with the "International Critical Tables."

Meter (M) equals	10^{0} Meter
Millimeter (mm.) equals	10^{-3} Meter
Micron (mu or μ)equals	10^{-6} Meter
Milli-micron (m mu or mμ)	10^{-9} Meter
Ångstrom (Å)	10^{-10} Meter
Double mu (mu mu or $\mu\mu$)	10^{-12} Meter
Milli-mu mu (m mu mu or m$\mu\mu$)	10^{-15} Meter

The micron should be defined as the millionth of a meter and not as the thousandth of a millimeter nor as a ten thousandth of a centimeter, as in some texts, although all are correct. Mu, the micron, is a millionth of a meter and the mu mu, double mu, or $\mu\mu$, is a mil-

lionth of a millionth of a meter. This is the micromicron. The milli mu or mμ, is a thousandth of a millionth of a meter. It is often *incorrectly* designated mu mu or μμ, which is a thousandth of a milli mu. In short, it is much simpler and much more easily understood if these small units are defined in terms of the meter using milli- for thousandth and mu for millionth.

S. FRANCIS HOWARD

NORWICH UNIVERSITY
NORTHFIELD, VERMONT

Cleaning Benches

To the Editor:

I don't know whether the following procedure is used or not in other labs but it has helped me a great deal in ours. In cleaning the tops of the chemical benches at Portland Technology we use a window squeegee instead of sponges. After a bench has been washed clean of the residues and stains which collect during the day we dry it with the rubber squeegee, pushing the excess water into the sink. This cleans and dries the bench in one motion, giving it a clean appearance in contrast to the sponge-cleaned bench, which usually dries spotty. Also, the time is more than cut in half, since the squeegee does not have to be squeezed out.

WALTER A. BECKER, Janitor

PORTLAND TECHNOLOGY
PORTLAND, MAINE

Double Decomposition of Salts

To the Editor:

In the August number of the JOURNAL OF CHEMICAL EDUCATION in an article entitled "Some Illustrations of Reactions between Solids," by H. S. van Klooster, the statement is made, "There are some examples of double decomposition of salts . . ." which statement is followed by some half dozen or so examples. The implication seems to be that such examples are not numerous. We feel that for the sake of completing the bibliography given with the paper attention should be called to a detailed study of sixty such reactions recently reported in the *Journal of the American Chemical Society*, **60,** 2320 (1938), and **62,** 766 (1940).

LYMAN J. WOOD

SAINT LOUIS UNIVERSITY SCHOOL OF MEDICINE
SAINT LOUIS, MISSOURI

Danger of Peroxide Formation

To the Editor:

You have had previous correspondence concerning peroxide formation in ethers. A recent experience in our laboratory may be of added significance in this connection.

A gallon can of isopropyl ether had been stored on a floor shelf of our storeroom for about four years. Approximately one-half of its contents had been used. The can had slowly corroded and within the past year or so, during which time I recall no use of its contents, small leaks had developed along the bottom seam and apparently the ether had slowly worked through and reacted with oxygen of the air to produce, near the bottom of the can, a coating of white solid material, portions of which were tinged yellowish brown with admixed iron rust. The first knowledge of this condition arose when the writer stepped between the shelves to get a bottle of some other material, and a bruising explosion occurred on the inside of the left foot. The detonation was similar to that resulting when a half gram or so of nitrogen iodide is set off. Except for momentary numbness there was no serious injury, possibly due to the fact that contact was made only at the edge of the shoe. A section of the leather sole was broken through and a crater four centimeters in diameter and eight-tenths centimeter deep in the center was made in the hard pine floor. Examination revealed solid crustlike material, some of which had sloughed off the can of isopropyl ether and become scattered out on the floor. Portions of this material detonated loudly when struck by a hammer or when heated.

Possibly it will be wise to keep this ether in brown glass bottles, with traces of water or some alcohol added, since sunlight and absence of moisture are said to be conducive to peroxide formation.

J. B. CULBERTSON

CORNELL COLLEGE
MOUNT VERNON, IOWA

More Written Work?

To the Editor:

The situation discussed in the letter from G. Wakeham of the University of Colorado in the October issue is admitted true by most of us who are teaching freshman chemistry.

It appears to me that one very large contributing factor in this regrettable circumstance is the almost complete elimination of written work from high-school science courses. The "more modern" educators seem to hold that the writing of reports and other assignments tends to disinterest the student. In addition to this, it must be admitted that the teachers in the past few years have had rather heavy teaching loads, and even those who have been willing have been handicapped by lack of time. Consequently, there has been an almost complete adoption of short form tests which do not fulfil completely the desired ends.

Rather recently, I attended a meeting at which the head of the department of education of a prominent state institution gave science teachers a talk upon "newer tests" in science. The "newer tests" were nothing more or less than true and false and other short form examinations. The speaker contended that these were definitely superior to the "describe, discuss, and explain" questions, and held that matters of that sort belong entirely to the English department, and are not the responsibility of the science teachers. Surely,

if our schools of education, which are producing the incoming teachers, are imparting to these young people such an attitude, we cannot expect very much improvement in the ability of high-school graduates to think in the constructive way toward which we believe a science study should assist them.

PAUL V. CLARK

JACKSON JUNIOR COLLEGE
JACKSON, MICHIGAN

What's Been Going On

In Applied Chemistry

VITAMIN C, known to the chemist as ascorbic acid, is about twice as plentiful in strawberries as it is in orange juice, according to studies conducted at the New York State Agricultural Experiment Station by Dr. Tressler and collaborators. Raspberries, turnips, and tomatoes are also good sources of this vitamin.

About 2,000,000 automobile bodies were treated during 1940 for rust-proofing by the phosphate treatment, to give a thin, tight, and uniform protective coating.

Petroleum is being discovered at the rate of 1,000,000,000 barrels a year in excess of the rate of consumption. The total oil reserves now amount to about 20,000,000,000 barrels, or enough to last about sixteen years at the present rate of consumption, according to Dr. Gustav Egloff of Universal Oil Products Company.

Ameripol, a copolymer of butadiene with "another material obtained from gas and air," is replacing fifty to one hundred per cent of the natural rubber in the new synthetic tire being produced by B. F. Goodrich Company. The synthesis has been perfected by Dr. W. L. Semon, formerly Professor of Chemistry at the University of Washington.

Blotting paper that is soaked in a fifteen per cent solution of hypo and bound to a freshly cut head of lettuce will prevent it from wilting for some time, as, for example, in transit from California to Chicago.

If you have "a pronounced ination and lack of vigor and vitality without other objective signs of disease," you have, according to Dr. Supplee, vitamin B_6 deficiency. This is known also as the vitality vitamin or the unknown factor.

A new approach to certain types of allergy such as hay fever, dusts, foods, danders, bacteria, heat, and cold, is treatment with vitamin C, which seems to be effective in the neutralization of the poisonous substance histamine, associated with these conditions.

According to Gustavus J. Esselen, wool from sheep's clothing, silk from the digestive system of worms, cotton from the parachutes of seeds, and linen from the stems of plants no longer limit the abilities of the textile industry to supply fabrics. You may have nylon fibers, glass fibers, or other synthetics to your own liking.

White interior finishes have been developed, according to D. F. Wilcox of the University of Cincinnati, which reflect up to seventy-two per cent of the ultra-violet light, thus making it possible to have indirect health-ray light for a room.

Buna N, which is a copolymer of butadiene with acrylonitrile, and Buna S, which is a copolymer of butadiene with styrene, are to be produced by the Firestone Tire and Rubber Company of Akron, Ohio, under a license agreement with the Standard Oil Development Company of New Jersey.

During the first quarter of 1940 there were no imports of synthetic camphor, as compared to 329,827 pounds during the same period in 1939.

Hydrogenolysis of wood, according to Professor Harold Hibbert, yields products which are water-white liquids that can be separated by fractional distillation without decomposition. A close kin to cyclohexanol, used in the nylon synthesis, is 4-*n*-propylcyclohexanol which is obtained in this hydrogenolysis. A new potential source of synthetic materials appears to be opened up by this degradation process.

The production of cellulose acetate molding compositions increased from 2,559,664 pounds during the first quarter of 1939 to 3,252,595 pounds during the corresponding period in 1940.

According to studies by Dr. Spencer of the Rockefeller Institute, sulfanilamide in concentrations of twenty to forty parts per million has a stimulating effect on the growth of roots of the tobacco plant but has no effect on uncut seedlings.

A semicommercial pilot plant is now in operation at Esso Laboratories, Bayway, New Jersey, for the production of butyl rubber, which is a copolymer of olefins and diolefins.

Armour and Company, Chicago, are operating a plant that is capable of separating about 15,000,000 pounds of drying oils annually by fractionation of the residues from the glycerol recovery. Such oils obtained from cottonseed, soybeans, and fish are being marketed at about 15 cents a pound whereas tung oils cost about 25 cents per pound.

Grapefruit oil is now being produced by fermentation, drying, and pressing of the grapefruit seeds, followed by treatment with caustic soda to remove the bitter constituent, limonin. This oil appears to be exceptionally good for sulfonation for the textile trade. It is estimated that there are about 15,000 tons of seeds available annually which will yield about 4,000,000 pounds of crude grapefruit oil.

P.E.T.N. is pentaerythritol tetranitrate and T_4 is cyclotrimethyltrinitramine, both of which are doubtless playing an important role as explosives in the present war.

At the close of 1938 there were 3192 corporations engaged in chemical manufacture in Japan.

—ED. F. DEGERING

In Cellulose Chemistry

IN THE consideration of cellulose, it should be noted that it was used originally as fuel and in the construction of a crude form of shelter, then as lumber in the building trades, as chips and pulp in the paper industry, as celotex in fabricated board, as plywood for the cabinet trades, as regenerated fibers for rayon synthesis, as embossed plywood for interior finishing, as plastic wood for repair work, as pressed board for construction, as seamless tubes for meats and sausages, and in hundreds of types of fabricated articles.

The production of lumber, according to authoritative sources, utilizes only about twenty per cent of the forests, whereas the new technic for the disintegration of wood into fibers and the subsequent recombination of these under heat and pressure to give pressed board, makes use of about ninety-three per cent of the forest crop. This represents a saving of seventy-three per cent and tremendously simplifies the important problem of reforestation.

This advance represents only one particular type of research in the cellulose field. Unpublished work carried on by the cellulose chemists, according to Dr. Heuser of the Paper Institute, Appleton, Wisconsin, includes research on cooking conditions in the digester that have led to a method for producing rayon pulp of any desired viscosity, on the bleaching of wood pulp with hypochlorite and chlorine that enables the production of rayon pulps of greater purity and of sufficiently low resin content to meet the requirements for producing high color in viscose yarn—as well as studies on the opaque color or milkiness of rayon, on the

aging of alkali-cellulose, on the acetylation and nitration of wood pulp, and on the types of wood pulps required in the manufacture of urea-formaldehyde plastics.

Problems now in progress at the Paper Institute include: the bleaching of wood pulp with oxides of nitrogen, the role played by alkali in the formation of suitable cellophane films, the mechanism of the action of sodium in liquid ammonia on cellulose, the role of the hydroxyl group in cellulose in the beating or hydration process, the problematical existence of a cementing material as a fiber constituent, and the dispersion of cellulose in cuprammonium solution.

The Bell Telephone Laboratories, according to Dr. Kohman, are conducting research on the ash-forming constituents of insulating paper, the adsorption of water by paper at elevated temperatures, the porous structure of paper in relation to drying and impregnation, the cation exchange of cellulosic materials, and cellulose as an insulating material.

Ethylcel (ethyl cellulose) has been developed and is being marketed by the Dow Chemical Company. It competes with cellulose acetate, cellulose nitrate, and similar products, and seems to have a very promising future.

Recent developments in both forestry and cellulose technology definitely point to the increased production of wood lots as a cash farm crop.

"There are ten thousand different products of cellulose being produced and the industry is still in its infancy," according to Vice President C. M. A. Stine of du Pont de Nemours and Company.

—ED. F. DEGERING

Out of the Editor's Basket

WE HAVE received a copy of "Visual Aids in the Realm of Chemistry," a bulletin issued (for twenty-five cents) by the Visual Aids Service New Jersey State Teachers College (Upper Montclair, New Jersey). It is an up-to-date list of sources of films, charts, exhibits, etc., covering all phases of chemistry. Brief descriptions, with prices quoted, make this valuable to teachers on the lookout for new material.

• A slight variation in an old demonstration experiment is suggested by Milton G. Wolf, of James Madison High School, Brooklyn, New York. To show the density of carbon dioxide, compared to air, one puts a fair-sized block of dry ice in the bottom of a large aquarium jar, blows soap bubbles and drops them in the jar, where they float on the gaseous carbon dioxide layer. The bubbles should be about two inches in diameter, and a little practice may be necessary to drop them in the jar properly. Use the soap solution described by G. A. Cook [J. CHEM. EDUC., **15**, 161 (1938)], and for best results blow the bubbles with an 8-mm. glass tube in series with a wash bottle to remove the CO_2 from the breath.

• There are many ways of demonstrating the oxygen content of the air, but a simple one has been suggested by O. E. Lanford of the New York State College for Teachers, in Albany. He uses a glass tube about two inches in diameter and eighteen to twenty-four inches long, with the lower end in a large beaker of water. A one-hole stopper holding a deflagrating spoon is provided for the upper end. Some phosphorus in the deflagrating spoon is ignited and lowered into the tube. As the oxygen is consumed, the change in volume is noted by means of a meter stick mounted along the tube.

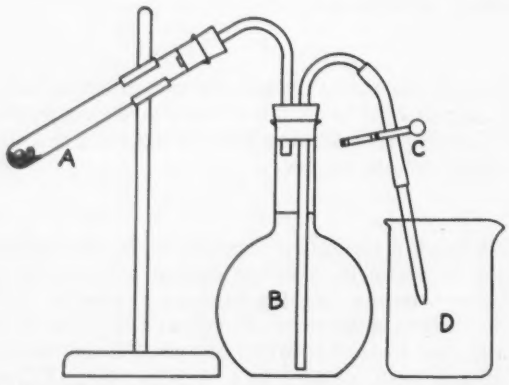
• If one has occasion to use small capacity fuses for electrical apparatus they can easily be made, following directions by M. H. Kalina, of the University of Saskatchewan. Draw a piece of ordinary glass tubing down to a capillary and break in half. Fill the large end of one piece with small particles of solder and melt them down to the capillary tube. Heat at this spot and draw the tube out quickly. The fine capillary which results will contain a thin thread of wire which can be freed from the glass covering by rolling between glass plates. With practice, wires can be drawn which fuse at currents as low as 200 milliamperes. If Wood's metal is available, the procedure is easier. The capillary is drawn down completely and heated in a steam bath, by suspending it from a stopper in a long test tube hanging in a Florence flask of boiling water. Small pieces of Wood's metal will melt and run into the capillary, with the help of a little air pressure.

• Jack De Ment of Portland, Oregon, writes to tell us that mercury can be removed from gold—on jewelry, for example—by rubbing a block of magnesia or a stick of chalk over the surface.

• Although a laboratory experiment on silver plating might be useful it is seldom carried out, due to the poisonous nature of the customary cyanide bath. A. E. Abbot, of Brooklyn Technical High School, observed that it can be carried out using iodide instead. A suitable bath contains 40 g. $AgNO_3$, 560 g. KI, and 2.8 cc. of concentrated H_2SO_4 per liter. A silver anode and copper cathode are used, the latter cleaned by dipping into concentrated HNO_3 until a matted surface appears. The circuit is adjusted by a suitable resistance to give a current density of about one ampere per $dm.^2$ of exposed cathode surface. Stir the bath mechanically and operate for about ten minutes.

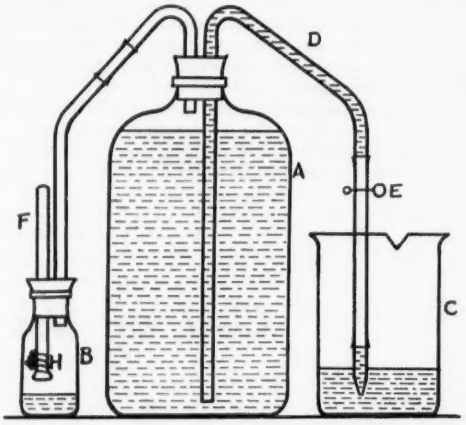
● Merck and Company (Rahway, New Jersey) have recently issued a booklet, "The Story of Vitamin B_1." Although not intended for general distribution, it is available to colleges and universities, research workers, "and to other individuals who are properly entitled to receive the brochure for their information and use." It is an interesting and authoritative seventy-page monograph on this important subject, containing excellent pictures of the research technic, and written in not too technical language.

● Most of our readers may be familiar with the apparatus pictured below, for the determination of the density of oxygen. We ourselves recognize it as an old friend—and a reliable one. Daniel R. Stull, of East Carolina Teachers' College, Greenville, North Carolina, who has sent us the drawing, seems to have one interesting variation in its use, however. Instead of weighing the test tube *A* and its load of $KClO_3$ (+ MnO_2), he uses two or three of the drugstore's five-grain tablets, which are uniform enough so that they need not be weighed individually (5 grains = 0.3240 gram). On heating to completion the O_2 is driven over into *B*, displacing water into the beaker *D*, which is subsequently measured in a graduate. The pinch clamp *C* is for adjustment before and after, and during the equalization of water levels. It is hardly necessary to list the various experimental precautions. The weight of the oxygen in this case is, of course, calculated from the weight of $KClO_3$ used. Admittedly approximate, the experiment yields results of surprisingly low experimental error, although there is a noticeable tendency to stop heating before the decomposition is complete.



APPARATUS FOR DETERMINATION OF THE DENSITY OF OXYGEN

● An apparatus very similar to that just described is suggested by Ching-pan Ts'ao, of Yenching University, Peiping, for the determination of the equivalent weight of metals. The various types of apparatus used for this experiment have drawbacks too well known to need discussion. This particular modification is shown in the illustration below. In the stopper of the small



bottle, *B*, is a glass rod, *F*, with a squashed-down end. The piece of metal is attached with copper or platinum wire and suspended above the dilute hydrochloric acid in the bottle. A tube communicates with the large bottle or flask, *A*, nearly full of water. The syphon tube, *D*, leading over into the beaker, *C*, is operated exactly as in the previous apparatus for the density of oxygen. The pressure in *A* is equalized with that of the atmosphere by adjusting water levels, the pinch-clamp, *E*, closed, and the beaker emptied. Then *E* is opened and if everything is airtight *F* is pushed down to lower the metal into the acid. When finished, *F* is raised to its original position, the pressures equalized, *E* closed, and the water in the beaker measured. For Al or Mg, 0.2 g. to 0.3 g. will be found satisfactory; for Zn, about one g. Mossy zinc will do very well if strips are not available.

● General Electric scientists, concentrating on United States defense problems, are working on a combination of light and glass which will allow daylight in through your windows during the day but keep light from shining out at night. By pitting one color against another, the G. E. lighting experts are working on the problem confronted by war-torn Europe: the danger of lighted windows guiding enemy planes.

H. A. Breeding, physicist at the Schenectady lighting laboratory, disclosed that a combination of blue-painted windows and sodium lighting in homes and factories is one answer to this particular defense problem. The paint to be used, Breeding said, is ordinary paint, treated with a special blue dye, experiments on which are still proceeding. Windows treated with this special blue paint will admit daylight. But, more important in war time, homes and factories can be lighted inside with sodium lights, not one flash of which will escape through the blue windows.

RECENT BOOKS

APPLIED CHEMISTRY. *Sherman R. Wilson*, Head of The Exact Science Department, Northwestern High School, Detroit, Michigan, and *Mary M. Mullins*, Chairman of Physical Science, New Utrecht High School, Brooklyn, New York. Henry Holt and Company, New York City, 1939. xiv + 530 pages. 244 figs. 13.5 × 20 cm. $1.72.

The difficulty of producing an applied text, to be used before the basic science has been taught, is evident throughout the book. Many of the topics have been treated quite as fully as one might wish for in the conventional chemistry course. This is necessary, perhaps, to supply the principles required for teaching the application, and it may be intended to satisfy those who are not yet willing to accept a purely applied text. The effect tends to lessen the interest that should develop from a study of the applications. In fact, in the case of acids, bases, and salts, the uses of these materials have been slighted.

The authors are to be commended for their contribution to the teaching of secondary science, and especially because of the reorganization in progress. The separation of the pure science from the applied is almost certain to provoke criticism.

K. M. PERSING

GLENVILLE HIGH SCHOOL
CLEVELAND, OHIO

INDIA RUBBER MAN, The Story of Charles Goodyear. *Ralph F. Wolf*. The Caxton Printers, Ltd., Caldwell, Idaho, 1939. 291 pp. 15 × 23.5 cm. $3.00.

The centenary of the discovery of the vulcanization of rubber was celebrated this year (1939), and this year also the first biography of the discoverer appeared. It is a dramatic story of hardship, poverty, suffering, disgrace, and of mingled success and failure, of success in accomplishing the conversion of gum rubber into a tough and elastic mass which retained its properties both in the warm and in the cold, and of failure to conserve the success properly and retain the profits from it. Goodyear's favorite reading was the Book of Job, for whose hero he must have felt a genuine sympathy.

Wolf's book represents extensive and careful research and is equipped with a lengthy bibliography. All points appear to be discussed adequately, the inventions of his children and descendants, his misfortunes, and his fanatic perseverance. Where there are conflicting stories, both or all of them are presented fairly.

Wolf quotes many interesting and important passages from Goodyear's own account of his experience as reported in the book, "Gum-Elastic and its Varieties, with a Detailed Account of its Applications and Uses, and of the Discovery of Vulcanization," (2 vols., published for the author at New Haven, 1855). Wolf's book is valuable because of the many quotations which it contains, and because it has been built up soundly from the sources.

TENNEY L. DAVIS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS

A TEXT-BOOK OF QUANTITATIVE CHEMICAL ANALYSIS. *Alex. Charles Cumming* and *Sydney Alexander Kay*, University of Edinburgh. Revised by *Francis Clint Guthrie* and *John Trengove Nance*, University of Liverpool. Seventh Edition. D. Van Nostrand Co., Inc., New York City, 1939. xv + 496 pp. 85 figs. 14 × 22 cm. $5.00.

This familiar English text on quantitative analysis which was first published in 1913 now appears in its seventh edition. This fact alone would seem to be proof of the usefulness and survival of the test of time. The treatment of the subject is entirely descriptive, with theory and equations reduced to the minimum and with no problems. The purpose of the text is to present in a systematic way to the student clear directions for carrying through an unusually wide variety of quantitative determinations, stressing technic and selecting the best method for each analysis.

GEORGE L. CLARK

UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

FUNDAMENTALS OF BIOCHEMISTRY, IN RELATION TO HUMAN PHYSIOLOGY. *T. R. Parsons*, B.Sc. (London), M.A. (Cantab.), Sidney Sussex College, Cambridge. Sixth Edition. William Wood and Company, Baltimore, 1939. xii + 461 pp. 26 figs. 12 × 18 cm. $3.00.

As a "most elementary introduction to the subject," to quote from the foreword, this book is eminently successful. The approach is easy and graceful, the style is simple and direct, and a minimum of preliminary knowledge of pure chemistry and physics is demanded. The ideas follow one another logically, with sufficient illustration and application to be interesting and plausible.

The treatment is very descriptive and not at all analytical. Controversial questions are avoided, a serene and stabilized attitude toward the subject matter is developed, and the critical or advanced student will find little basis for the conviction which follows upon doubt and weighing of evidence.

For its ready understandability, its compactness, its breadth of subject matter, and its freedom from errors, this book is to be recommended as an elementary descriptive introduction to biochemistry.

MARTIN E. HANKE

THE UNIVERSITY OF CHICAGO
CHICAGO, ILLINOIS

INTRODUCTION TO EXPERIMENTAL COOKERY. *E. H. Nason*, Ph.D. Professor of Foods, Syracuse University. McGraw-Hill Book Co., Inc., New York City, 1939. ix + 317 pp. 15 figs. 13.5 × 21 cm. $2.75.

Experimental cookery is defined herein as an introduction to food research, one which shows its value, its scope and its technics. To these ends, the subject matter of the book is presented under seventeen chapter headings. Following an introductory chapter in which this "most interesting phase of the study of foods" is rather fully discussed, come others devoted to discussions on acidity, flavor, the scoring of foods, fundamental concepts of colloids, jellies, foams, emulsions, new concepts of proteins, eggs and egg cookery, flours, batters and doughs, crystallization, fruits and vegetables, meat cookery, and recipes, old and new. Alice E. Ebersold has contributed to the list a chapter on a timely subject, an introduction to statistical measurements.

It is a matter of regret to the reviewer that the author should have occasionally resorted to the use of trade rather than descriptive names in describing foods.

We have come a long way in the field of experimental cookery since the days of Frederick Accum and his CULINARY CHEMISTRY (1821). The present work in a sense reflects the progress which has been made in the past twelve decades in the application of chemistry to this field. The author is to be commended for her successful efforts in making this information available in a readily understandable form. A careful study of its pages should familiarize the student with reliable information about foods, modern trends in food research, and the technics employed in this branch of food chemistry.

H. A. SCHUETTE

UNIVERSITY OF WISCONSIN
MADISON, WISCONSIN

CALCULATIONS OF QUANTITATIVE ANALYSIS. *Carl J. Engelder*, University of Pittsburgh, John Wiley and Sons, Inc., New York City, 1939. vi + 174 pp. 14 × 22 cm. $2.00.

As another of the series of familiar and excellent textbooks in the field of analytical chemistry by this author appears this little book presenting three hundred original problems. These new problems are arranged in fifteen sets, each of which illustrates a fundamental subject in the field of quantitative analysis. One set is supposed to cover a weekly assignment supplementary to the conventional semester's work in elementary quantitative analysis. Discussion of theory together with numerous illustrative examples accompanies each problem set. Odd-numbered problems with answers are intended for home assignments; even-numbered problems without answers are suited for classroom work, quizzes, or examinations. The general style, therefore, is parallel with the author's book, CALCULATIONS OF QUALITATIVE ANALYSIS.

GEORGE L. CLARK

UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

THE BOOK OF DIAMONDS. *J. W. Hershey*, McPherson College, McPherson, Kansas. Hearthside Press, New York City, 1940. xii + 142 pp. 11 figs. 15 × 23 cm. $2.00.

This book was written for the general reading public as well as high-school and college students who have a desire to learn something of the non-technical aspects of science. The author has accomplished in an excellent manner his desire that it interest the reader without sacrificing accuracy.

Starting with a fascinating chapter on "The Early History of Diamonds" the story of the "King of Gems" is carried through chapters on "Superstitions and Religious Uses of Precious Stones," "Brazilian Diamonds," "South African Diamonds," "Diamonds Found in Other Parts of the World," "Properties and Tests for Diamonds," "Cutting Diamonds," "Remarkable Diamonds and Gems," "Other Precious Stones," "The Buying and Uses of Diamonds," and "How to Make Synthetic Diamonds." This last chapter is of especial interest to the chemist, since the author, who is credited with having made the largest synthetic diamonds on record, reviews his many experiments in connection with this work.

Among the illustrations is an attractive plate showing fifty-two varieties of precious and semi-precious stones in their natural colors.

All who in any way have an interest in diamonds will find this book both profitable and enjoyable reading.

J. W. HOWARD

MONTANA STATE UNIVERSITY
MISSOULA, MONTANA

CHEMICAL INDUSTRIES. *D. M. Newitt*, Editor. Leonard Hill Ltd., London, 1940. Fourteenth Edition. xviii + 364 + lxxix pp. 21.5 × 28 cm. $4.00.

In order to fulfil its purpose as "a compilation of the data and information essential to the conduct of all process industries," the fourteenth edition of CHEMICAL INDUSTRIES contains facts concerning the constructional materials for the chemical industry; the power plant and water treatment; factory equipment, layout, and location; size reduction; the mixing and blending plant; separating and grading, handling, conveying and transport of materials; instruments and laboratory apparatus; raw and partly manufactured materials and heavy chemicals; the raw materials of perfumery; fine chemicals, pharmaceutical perfumery and drugs; mathematical tables; and a comprehensive bibliography.

In addition to this wealth of information on "processes of manufacture entailing chemical or other scientific formulae, with a list of materials, plant, equipment and raw products necessary for these trades," CHEMICAL INDUSTRIES contains indexes to subject matter, to advertisers, to commodities, to trade names and marks. The organization of the material is such that specific information is readily available.

CHEMICAL PUBLICATIONS, THEIR NATURE AND USE. *M. G. Mellon*, Ph.D., Professor of Analytical Chemistry, Purdue University. Second Edition. McGraw-Hill Book Co., Inc., New York City, 1940. xii + 284 pp. 4 figs. $2.75.

The new edition of Professor Mellon's book on the use of chemical publications emphasizes the three objects of the first edition: (1) to discuss the origin of chemical literature, (2) to present lists of source material, and (3) to offer means of training students in the use of this material. In each of these departments, the book has been enlarged, markedly improved, and brought up to date. It demonstrates the increased volume of chemical literature of the past twelve years by the lengthened bibliographical lists in the body of the text.

In addition to the fields formerly covered in the first edition, several new ones are discussed. They are selected fields of applied chemistry including metallurgy, biochemistry, and agricultural chemistry in the main text, and helpful information concerning physics and engineering in the appendix. There is one entirely new chapter on some miscellaneous compilations of secondary sources such as recipe books, catalogs and biographical works which are of use as reference books.

For the teacher of courses in the use of chemical literature, this book continues to include excellent, specific problems for the student to use in practice in literature searching. These have increased in number from fourteen to nineteen, although the individual assignments for each question have been reduced by half. Among the new problems are those relating to metallurgical, medical, pharmaceutical, and dye chemistry, and matters of interest to the industrial chemist, such as an economic survey of a chemical commodity, or a financial report.

The combined text and problems make this book particularly advantageous to anyone teaching this type of work for the first time. This edition has been carefully compiled and assembled, giving an excellent result for but slight additional cost.

VIRGINIA BARTOW

UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

THE STRUCTURE OF METALS AND ALLOYS. *W. Hume-Rothery*. Chemical Publishing Company, New York City, 1939. 120 pp. 13 × 22 cm. $1.75.

The monograph was originally published in 1936 and has now been rewritten. It begins with an introductory chapter on the "Electronic Background to Metallurgy" which has been made intelligible to readers of little formal training in recent physics and chemistry. Then follow the chapters, "The Crystal Structure of the Elements," "The Atomic Radii of the Elements," "Primary Metallic Solid Solutions," "Intermediate Phases in Alloy Systems," and "Imperfections in Crystals and Deviations from the Ideal Lattice."

Especial emphasis is given to the advances of the last fifteen years which may be related to the electronic structure of metals. The author demonstrates that a great deal of the rather elaborate development can be described in elementary terms and exemplified by particular solid solutions and alloy systems. The interesting regularities first recognized by the author himself, the so-called electronic-compounds, have been given scant theoretical discussion.

After reading the monograph one would no longer hesitate to include in the undergraduate curriculum an introduction to the electronic structure of metals.

SIMON FREED

THE UNIVERSITY OF CHICAGO
CHICAGO, ILLINOIS

MELLOR'S MODERN INORGANIC CHEMISTRY. *G. D. Parkes* and *J. W. Mellor*. Longmans, Green and Company, New York City, 1939. xix + 915 pp. 13.5 × 22 cm. $4.50.

This new edition embodies extensive changes in comparison with the previous editions, due to the great development of the subject since the book was first written. It is now virtually a new book.

LECTURE DEMONSTRATIONS IN GENERAL CHEMISTRY. *Paul Arthur*, Assistant Professor of General and Analytical Chemistry, Oklahoma Agricultural and Mechanical College. McGraw-Hill Book Co., Inc., New York and London, 1939. xvi + 455 pp. 14 × 21 cm. $4.00.

This book is an actual laboratory manual for the lecture demonstrator in general chemistry. Specific and detailed directions for almost a thousand experiments are grouped under one hundred seventy-five headings; an extended system of cross references readily adapts the material to any textbook. Often the procedure is preceded by a brief statement of the chief principle to be demonstrated; other rules or theories which can be reviewed or introduced are also mentioned along with laboratory operations and industrial applications.

The value of the book is enhanced by a rather complete bibliography of articles on lecture demonstrations which have appeared in this JOURNAL and in *School Science and Mathematics*. References to a few other journals and books are included.

Experienced teachers of general chemistry should be grateful to Dr. Arthur for this careful compilation and presentation of widely scattered material. For younger teachers the book is invaluable. The manual should prove especially worth while for those who have to offer survey courses or courses with greatly curtailed laboratory periods. It is the hope of the reviewer that this book will inspire the publication in this JOURNAL of new and improved demonstrations.

Attention should be called to the companion volume, "Demonstration Experiments in Physics," edited by Dr. R. M. Sutton and published by the same company, which includes many excellent demonstrations of physico-chemical phenomena.

EDWARD L. HAENISCH

VILLANOVA COLLEGE
VILLANOVA, PENNSYLVANIA

A HISTORY OF CHEMISTRY. *F. J. Moore*, Ph.D., Late Professor of Organic Chemistry in the Massachusetts Institute of Technology. Revision prepared by *William T. Hall*, Associate Professor of Analytical Chemistry in the Massachusetts Institute of Technology. Third Edition. McGraw-Hill Book Company, Inc., New York and London, 1939. 14 × 20 cm. xxi + 447 pages. $3.00.

The third edition of Moore's book is a great improvement over the earlier editions. In the second edition certain errors and infelicities of the first were rectified, and the second was interesting and sound as far as it went. In the third Professor Hall has incorporated much new material, with the result that nothing of importance on the history of chemistry after the Middle Ages is omitted—and the attractive textbook is probably the best within its field in the English language. Its account of early chemistry is correct, but still too brief. For a complete course in the history of chemistry a second text, which treats more fully of early chemistry and alchemy, is needed in addition.

TENNEY L. DAVIS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS

PYROTECHNY, A PRACTICAL MANUAL FOR MANUFACTURERS OF FIREWORKS, SIGNALS, FLARES AND PYROTECHNIC DISPLAYS. *George W. Weingart*. Chemical Publishing Co., Inc., New York City, 1939. 182 pp. 85 figs. 4 full-page colored illustrations. 14 × 21 cm. $5.00.

This book, which describes methods and recipes for making numerous types of fireworks in small and large amounts, undoubtedly represents an important contribution to the art of pyrotechny and can be recommended as a reference book and guide for anybody interested in this subject. It is suggested, however, that the book can be made more attractive by the use of better paper, better illustrations, elimination of archaic terms, thorough revision of certain grammatical constructions and more careful proofreading.

LEOPOLD SCHEFLAN

PYRENE MANUFACTURING COMPANY
NEWARK, NEW JERSEY

INTERMEDIATE CHEMICAL CALCULATIONS. *J. R. Partington*, M.B.E., D.Sc., Professor of Chemistry, and *Kathleen Stratton*, M.Sc., Lecturer in Chemistry, in the University of London, Queen Mary College. First Edition. Macmillan and Co., Ltd., London, 1939. x + 239 pp. 2 figs. 13 × 20 cm. $1.65.

The title and preface of the book imply that a course of chemical calculations is provided, "intermediate in standard between the [English] General School Certificate Examination and the examination for the B.Sc. degree"; it being generally understood that the working of numerical problems is practically indispensable to the clear understanding of chemical principles.

In order not to duplicate the explanatory material available in many textbooks, such material is here reduced to a minimum. After a brief statement of a law or principle, examples are worked out, followed by a set of problems, the answers to which are given in the appendix. More difficult problems are starred, in order that they may be omitted if the scope of the course makes this advisable.

The twelve chapters include such topics as the gas laws and solubility of gases; vapor density and molecular weights of gases; volumetric composition of gases and gas analysis; equivalent and atomic weights; gravimetric analysis; volumetric analysis; organic analysis; molecular weights in solution; thermochemistry; law of mass action and chemical equilibrium; electrolysis and electrolytic dissociation; equilibrium in solutions of electrolytes. The appendix contains directions for the drawing of a nomogram for the reduction of gas volumes, tables of normal densities and vapor pressures, atomic weights, logarithms, and antilogarithms.

The book should prove useful as a supplement to classroom instruction, and its numerous problems with answers should be of value to the teacher of classes in introductory courses as well as in later courses of analytical and physical chemistry, whether or not the methods of calculation presented will be approved in all instances by the instructor. In particular, in the chapter on volumetric analysis including oxidation reactions, those who employ methods of calculation based upon the concepts of milli-equivalent weights and valence change may consider the procedures here recommended somewhat circuitous. An explanation of the balancing of chemical equations by the method of valence change would have been a desirable adjunct to this part of the book. Taken as a whole, the book is to be recommended as of definite value, particularly as an aid to the teacher in the assignment of home problems and to the student in clarifying the principles expounded to him in lectures and recitations.

WALTER C. SCHUMB

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS

INTRODUCTION TO PRACTICAL ORGANIC CHEMISTRY. *Frederick George Mann*, Trinity College, Cambridge, and *Bernard Charles Saunders*, Magdalene College, Cambridge. Longmans, Green and Co., New York City, 1939. ix + 191 pp. 36 figs. 13.6 × 21.7 cm. $1.50.

This manual is an abridged version of the authors' larger text, PRACTICAL ORGANIC CHEMISTRY, the second edition of which was published late in 1938. After describing methods and manipulation in Part I (26 pp.), directions for 42 preparations are given in Part II (64 pp.). Part III (57 pp.) describes some of the reactions useful in characterizing organic compounds and Part IV (24 pp.) gives a few macro quantitative methods. The appendix (10 pp.) gives directions for the preparation of reagents, first aid information, and numerical tables. A good index is provided.

This brief manual is intended for students who are not proceeding on to more advanced work, and to provide a source of information for certain types of examinations given in Great Britain.

R. L. SHRINER

UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

THE TEACHING OF SCIENCE IN ELEMENTARY AND SECONDARY SCHOOLS. *Victor H. Noll.* Longmans, Green & Co., New York City, 1939. viii + 238 pp. 8 figs. 13.5 × 21.5 cm. $2.00.

In a bibliography of 400 titles the author cites many articles reporting investigations in the teaching of science. The body of the book summarizes their results and points out their significance to the teacher under the scientific attitude (17 pp.), methods (31 pp.), the science curriculum (82 pp.), measurement of achievement (79 pp.), the science teacher's qualifications (18 pp.). According to the index the major items under chemistry are the content of the chemistry texts (3 pp.), diagnostic studies (4 pp.), tests (4 pp.). But the chemistry teacher will profit by the results of the many studies even though the subject matter taught by the investigator was not chemistry. All science teachers will be grateful for this list and interpretation of investigations in the teaching of science.

The reviewer hesitates to call attention to the omission from the bibliography of his own "Introduction to the Teaching of Science" (1934)—a book of similar purpose. The author will find in it summaries of a number of investigations which he has also omitted from his bibliography and which seem important to the reviewer. Ignorance of this body of readily available material seems rather inexcusable.

The author gives a list of "The Best Available Tests in Science" without indicating any basis for his selection. His readers might like a list of those he relegates to the limbo of the undesirable in order to form their own judgments.

E. R. DOWNING

THE UNIVERSITY OF CHICAGO
CHICAGO, ILLINOIS

TECHNICAL ANALYSIS OF ORES AND METALLURGICAL PRODUCTS. *F. D. Hills,* Chemist, Experimental Plant, Colorado School of Mines. Second Edition, Revised. Chemical Publishing Co., Inc., New York City, 1939. xiv + 250 pp. 14 × 21 cm. $3.00.

The author has endeavored to present something different from the run-of-mine texts in metallurgical analysis by correlating results with the accounting procedures as practiced in the usual plant. The theme, "no analytical method is of universal application" is successfully accomplished. The author's wide experience has enabled him to discuss accurately the application of different methods.

C. F. BAKER

TUFTS COLLEGE
BOSTON, MASSACHUSETTS

THE COMPOSITION OF ANCIENT GREEK BRONZE COINS. *Earl Radcliffe Caley,* Assistant Professor of Chemistry, Princeton University. Memoirs of the American Philosophical Society, Volume XI, 1939. The American Philosophical Society, Independence Square, Philadelphia, 1939. viii + 203 pp. 4 plates. 15 × 23 cm. Paper bound, $2.50.

This publication is an account of the best work which has yet been done on the careful and complete analysis of ancient Greek bronze coins of known authenticity. The results, rigorously established and set down with scientific precision, are data for the use of the student of political and economic history. They indicate, or really demonstrate, the changing prosperity of the Greek cities, the probable influx of coinage metal from Carthage after its destruction, and the increasing influence of Rome in the Mediterranean world.

The book is a contribution less to chemistry than to the data of history. It is less a book to be read than a book to support conclusions. Professor Caley's own conclusions are extremely interesting, and illustrate clearly the way in which the results of chemical studies on archeological objects may contribute to our insight into the social and economic processes of the past.

TENNEY L. DAVIS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS

MODERN METHODS AND MATERIALS FOR TEACHING SCIENCE. *E. D. Heiss,* Ph.D., Professor and Head of the Science Department, State Teachers College, East Stroudsburg, Pa., *E. S. Obourn,* B.S., Head of Science Department, John Burroughs School, Clayton, Mo., *C. W. Hoffman,* M.A., Instructor of Science, Blair Academy, Blairstown, N. J. The Macmillan Co., New York City, 1940. x + 347 pp. 27 figs. 14 × 21 cm. $2.50.

Section I, one hundred forty pages, is devoted to the principles of science teaching, Section II, one hundred thirty-two pages, to visual and other sensory aids, Section III, seventy-seven pages, to sources of materials. The aim of science teaching is to help pupils adjust themselves to a rapidly changing environment in which science is playing a prominent part. Science can contribute a group (1) of interpretive understandings, (2) of appreciations, (3) of attitudes or mind-sets, and (4) a method of attack on problems.

The book provides a good bibliography of books and articles. It reports faithfully the content of many of these, but it comes to no conclusions. The chapters on the psychology of science teaching, methods, laboratory and demonstration, importance of reading, evaluation of learning, present valuable abstracts, and perhaps it is best to let the reader draw his own conclusions. The beginning teacher may wish counsel.

Section III lists titles of books and periodicals with their publishers, sources of pictures, models, charts, films. Science pupils need to study things at first hand. Such "aids" may be distractions unless used with moderation and discretion. Supply houses and publishers are in business to sell goods, not to educate youngsters.

Every science teacher would be stimulated to more thoughtful procedures by reading Section I. The other sections will be used for occasional reference. The book will appeal most to teachers of general science and biology.

ELLIOT R. DOWNING

THE UNIVERSITY OF CHICAGO
CHICAGO, ILLINOIS

DEPENDABLE MODERN TREATMENTS FOR BURNS. *Harold Joe Davis.* Underhill Press, Beebe, Arkansas, 1940. 8 pp. 10 × 16 cm. $.50.

In this pamphlet the author discusses the various kinds and degrees of burns, giving valuable information and advice regarding first-aid treatment. Special attention is given to eye burns, burns from chemicals, and powder burns. Various modern treatments for burns are discussed briefly. A two-page glossary of terms used in discussing burns and treatments concludes the pamphlet.

The author's connections and training are not given, and there is no bibliography of source materials. The price of fifty cents seems high, as similar pamphlets treating the same subjects are available from various authoritative sources, some of them free on request and others at from five to ten cents each.

J. O. FRANK

STATE TEACHERS COLLEGE
OSHKOSH, WISCONSIN

A PRACTICAL MANUAL OF CHEMICAL ENGINEERING. *Harold Tongue,* Principal Assistant; The Chief Engineer's Department, The London County Council. Foreword by *Sir Gilbert Morgan.* D. Van Nostrand Company, Inc., New York City, 1939. xv + 560 pp. 305 figs. 15 × 24.5 cm. $12.00 (net).

The author states that the practical manual of chemical engineering resulted from the expansion of notes, collected over twenty years, on the design and construction of chemical process plants. This book, therefore, was compiled as a manual of reference for those engaged in problems of chemical plant design and operation rather than as a formal academic text.

C. W. SIMMONS

LEHIGH UNIVERSITY
BETHLEHEM, PENNSYLVANIA

Annual Index—Journal of Chemical Education

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